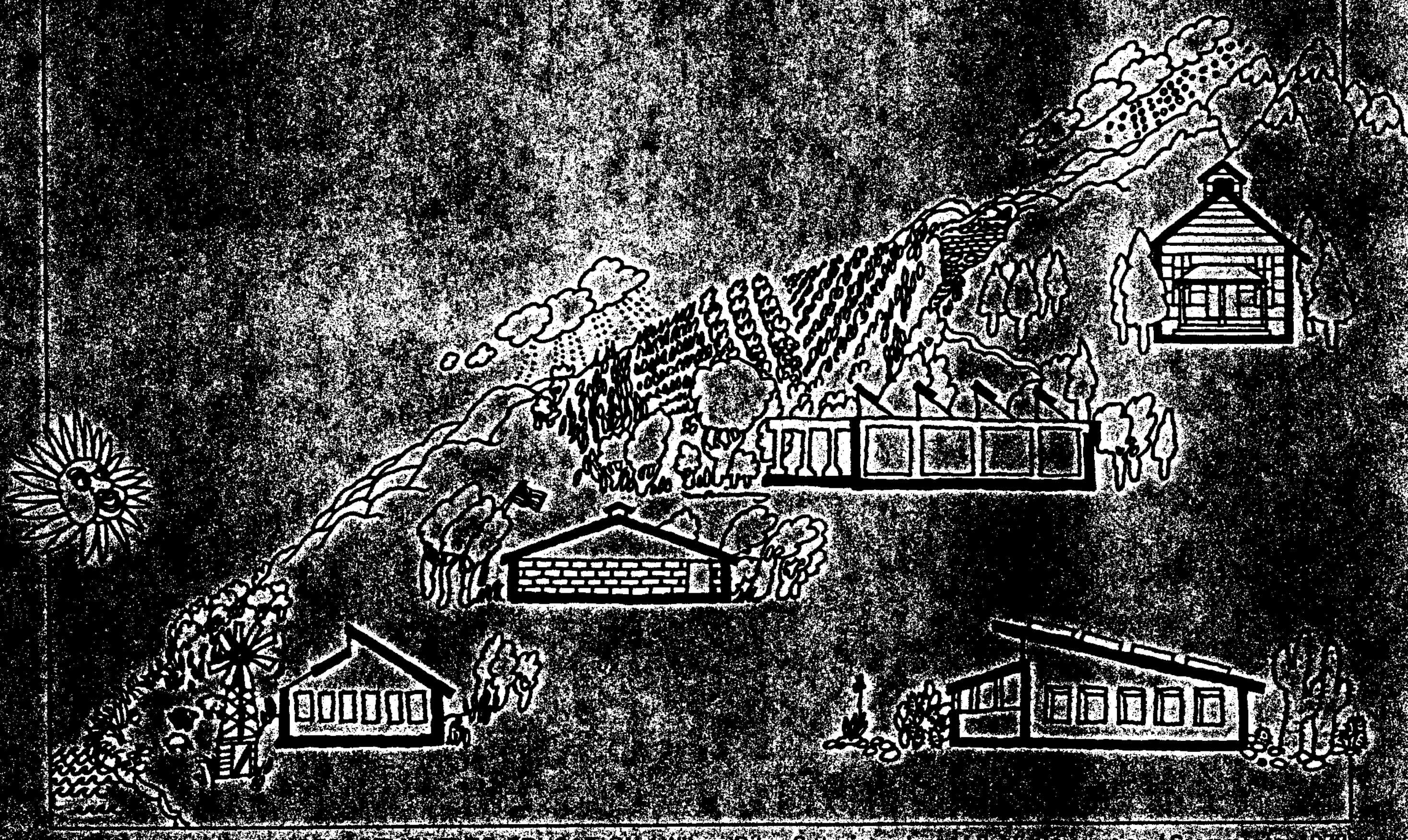
# CALIFORNIA SCHOOL ENERGY CONCEPTS, 1978



CALIFORNIA STATE DEPARTMENT OF EDUCATION / Wilson Riles, Superintendent of Public Instruction / Sacramento, 1978

# California School Energy Concepts, 1978

Prepared by the

Bureau of School Facilities Planning
California State Department of Education

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# Foreword

As we all know, the energy crisis is still very much with us. Fuel costs are rising and will continue to rise. Indeed, energy costs are increasing so rapidly that the most we can hope to achieve through energy conservation measures in many cases is "cost avoidance," rather than actual dollar savings.

Therefore, it is vital that all persons involved in education—custodian, teacher, student, administrator, and school board member alike—be constantly aware of the need to conserve energy and to work diligently at this task.

I urge you to examine closely the conservation suggestions in this publication and to implement as many as possible and practicable. I am not encouraging conservation at the expense of the health and safety of the human beings in our facilities or of the learning processes of our children. However, wasteful and careless practices *must* be eliminated and replaced by thoughtful, efficient management of natural resources.

By reducing the consumption of energy, our schools can set an example of the conservationists' attitude that today's students will need as tomorrow's adults.

I know I can count on the best efforts of all involved in dealing with this complex problem.

*Superintendent of Public Instruction*

# Preface

On March 1, 1977, the Bureau of School Facilities Planning, California State Department of Education, received an allocation under Title II of the Public Works Employment Act of 1976 for a project designed to promote energy conservation in California schools. This publication is one of the major efforts of that project.

In August, 1977, the bureau sent a letter to all school districts and many school architects in the state requesting information on their independent efforts to conserve energy. At the same time, the bureau staff continued research on published articles and reports. The replies to the bureau's request were carefully reviewed and followed up when appropriate, and individual items were categorized and tabulated. Over 100 schools, engineers, and architects were visited or telephoned. The suggestions that were common to the most respondents are emphasized in this publication.

*California School Energy Concepts, 1978* provides suggestions that can be adapted at individual school facilities to reduce energy consumption. It also focuses on the major concepts of the new state standards for energy conservation for new nonresidential buildings and contains explanations of how these standards affect schools. It is hoped that this effort will help California school districts to achieve maximum energy-efficient and cost-efficient operation of their facilities.

Bureau staff members responsible for preparing this publication were Ralph J. Askin, Supervising Architectural Adviser; Nancy Hardaker and Larry Martz, research writers; Dené Hedrick, Delineator; Fred Sanbongi, Engineer; and Jean Marquez, Office Assistant.

The staff of the Bureau of School Facilities Planning would like to express its appreciation to all who contributed their time, effort, and specialized knowledge to this publication and to the urgent goal of energy conservation.

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# Contents

# Introduction

America's crisis is not a crisis of energy or a crisis of the environment. It's a crisis of attitude.

Recognizing the mistakes of the past, let's roll up our sleeves, correct those mistakes, and create a civilization worthy of the name.

Let's plan our cities to let the sunshine in.

Let's design our living environment so that man and nature are compatible. Let's grapple with the energy issue as if life depended upon it. Because it does.[1]

Walter J. Hickel, former Secretary of the Interior and former Governor of Alaska

### The Problem

In the 1974-75 school year, energy use cost America's school districts approximately $1.5 billion, an increase of 55 percent from 1972-73.[2] School administrators across the country are concerned and alarmed about the energy situation. In the next century this situation may conceivably be alleviated through the development of abundant, inexpensive, nonpolluting sources of energy. Techniques for producing or using solar, wind, geothermal, and nuclear energy may be refined; and the costs for their production or use may be lowered.

For the next few decades, however, this country's primary needs will have to be met by diminishing supplies of the traditional fossil fuels—oil, natural gas, and coal—at constantly escalating costs.

### The Evolution of Architectural Techniques

An examination of the evolution of architectural techniques is helpful in attempting to understand the nation's energy dilemma. Early "architects" designed their buildings with climate in mind. They had no other choice. They had no thermostats to turn up when the weather was chilly, no light switches to throw after dark.

Ancient Egyptian architects built thick, windowless walls and flat stone roofs to keep out the intense heat. Light came through door openings and slits in roofs. In early Greece porticoes and colonnades protected people from the hot summer sun and sudden winter showers.

Rome's temperate to near tropical climate made courtyards and gardens common. In central Italy small windows and thick walls gave protection from the brilliant sunshine. As their empire expanded, the Romans came into contact with the architectures of other cultures and adapted them to their use. They developed sophisticated solutions to the problems of space comfort, among them the first highly developed central heating system. Large Roman houses even had two sets of living and dining rooms for comfort in both summer and winter.

Between the eighth and twelfth centuries, Romanesque architects in northern Europe built large window and door openings to admit light, and most buildings featured massive masonry and steep roofs to drain off rain and snow. The pitch of roofs was often reduced in parts of Scandinavia, however, to allow dry snow to act as insulation. In sunny southern Europe windows were smaller, and roofs were flatter.

In medieval England large windows were used to brighten dreary rooms, and high-pitched roofs served to shed rain and snow. Entrances to English cathedrals were generally in the form of porches that faced to the southwest and screened against direct winds. Movable shutters in Belgium and Holland warded off driving rain, and belts of trees acted as windscreens.

Many of these architectural techniques were brought to colonial America from Europe and were adapted to the new climate and available materials.

A remarkable similarity can be noted between architectural features and certain climates all over the world. It is not by coincidence that totally different cultures have developed like solutions to similar environmental challenges. In general, architectural techniques have followed these guidelines:

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[1]Walter J. Hickel, "We're Not Really Running Out of Resources," *New Worlds*, Vol. 8 (October-November, 1977), 31.

[2]These figures are from an untitled Federal Energy Administration undated survey of school energy use and costs for school years 1972-73 and 1974-75. Survey forms were sent to 10,000 school district superintendents across the country. Almost 3,000 responses were received. The figures are estimates based on a sample of 498 school districts selected as being representative of the nation as a whole.

1. The hotter the sun, the smaller the windows and thicker the walls.
2. The drier the overall climate, the flatter the roofs.
3. The colder and wetter the climate, the steeper the roofs.
4. The drearier the climate, the larger the windows (for lighting).
5. The windier the climate, the more protective devices (trees, shutters, walls, and so forth).

## Schoolhouse Architecture

School architecture has paralleled the architecture of other buildings, although schools did not evolve as independent structures until the nineteenth century. In early Athens "school" per se did not exist. A slave would simply escort the sons of well-to-do citizens from teacher to teacher, each of whom specialized in a certain subject.

Schools in ancient Rome were private schools and were held in whatever structure was convenient. Teachers conducted elementary classes in their own homes, in porticoes, or in the public colonnades of the forum. Lecture halls for higher education have been found in connection with private baths.

During the Middle Ages the Roman Catholic church ran cathedral and monastery schools in Europe chiefly to train young men for the priesthood. Convents performed a similar function for young women.

Widespread development of public schools did not begin until the early 1800s; and by the mid-1800s, the United States, Canada, and many European countries had established public school systems.

One-room schools such as the old Columbia Hill School (now part of San Juan Ridge Union Elementary School, San Juan Ridge Union Elementary School District, Nevada City) were the rule in the United States until about 1850.

In the United States schoolhouses were similar in construction to the other buildings in their region, and one-room schools were the rule until about 1850. In 1848 the first fully-graded public school in the United States, Quincy Grammar School, an imposing four-story building, was built in Boston. It was the prototype for the huge multiple-story "monuments" that dominated American schoolhouse architecture until the end of the 1930s, with their various lavish facades of Gothic, Victorian, Spanish Colonial, or other design borrowed from the past.

Imposing multiple-story structures dominated American schoolhouse architecture from about 1850 until the end of the 1930s.

During the early twentieth century, substantial improvements were made in heating, lighting, toilet facilities, space per pupil, and fire safety. School architecture remained essentially at a standstill, however, until 1935, when schools such as the low, sprawling Corona Avenue School in Bell, California, and Ansonia High School in Ansonia, Connecticut, were constructed. Such schools were major factors in the modernization of school design and were models for the functional, comfort-controlled schools of the present.

Before the industrial revolution climate had been given at least some consideration in the design of buildings because a fireplace, pot-bellied stove, or coal furnace alone was rarely adequate as protection against frigid winds and below-freezing temperatures. Technological advances of the late nineteenth and early twentieth centuries, however, and improvements in mechanical temperature control systems through the years freed architects from the restraints of the past, sparking a minor revolution in the architectural world. Talbot Hamlin writes:

> The architects of the 1920's had another concept which was in its way a stultifying one: the theory that modern—that is, according to their interpretation, new—methods of construction and new materials must always be chosen for every problem that presented itself, whatever the local or regional conditions might be. Climate could be disregarded, for mechanical heating and cooling devices make a building independent of its region—provided there is [*sic*] enough money and space for them. In other words, instead of cooperating with nature, many architects of this decade felt that an almost arrogant disregard for nature was the only truly "modern" attitude.[3]

In the 1930s the arrogance abated somewhat; and climate, site, and orientation were once again considered, at least partially, in planning buildings. However, the damage of technological advance had been done. The ability to control the indoor environment almost completely had irreversibly changed America's concepts of comfort. *Planning America's School Buildings,* a 1960 publication of the American Association of School Administrators, contains the following: "It is rather paradoxical that the more refinements we build into our artificial indoor climates, the more sensitive we seem to become to the slightest variation in temperature or air movement."[4] Such sensitivity is energy expensive, as are the regulations that technological improvements have fostered for schools. When central heating became common, demands increased for fresh-air ventilation in specified, often excessive amounts, thereby placing a heavy burden on heating systems and considerably increasing fuel needs and operating costs. When electric lighting became the primary source of illumination in schools, standards, now called extreme by many, were developed, increasing energy use and cost. Air conditioning, an unaffordable luxury in most schools in the 1960s, is commonplace today and is a major energy user.

Now, with the energy situation so apparent, concepts of comfort are, with difficulty, being readjusted. Architects are "rediscovering" many of the techniques for climate control that have existed since the time of ancient Egypt but that were discarded or lowered in priority during the era of cheap energy. Techniques like shading windows from the sun and planting deciduous trees as windbreaks, which were used in schools in the 1950s and 1960s to add comfort and save on fuel costs, are now being considered for their energy-saving potential. Others, like double glazing and heavy insulation, once considered too expensive, are now being adopted for their long-range, "life-cycle" benefits.

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[3]Talbot Hamlin, *Architecture Through the Ages.* New York: G. P. Putnam's Sons, 1953, p. 633.

[4]*Planning America's School Buildings.* Prepared by the American Association of School Administrators School-Building Commission. Washington: American Association of School Administrators, 1960, p. 117.

# Energy Sources

This section is devoted to discussions of traditional fuels, "new" fuels, and fuels of the future.

### Traditional Fuels

Wood was the first fuel people used to produce energy. Later they learned to use wind and water for power; and, until the 1800s, these three fuels were the primary energy sources in the United States. Today fossil fuels—coal, oil, and natural gas—have almost entirely replaced wood, wind, and water as basic sources of energy in this country.

#### Coal

Coal was used for heating in Europe as early as the thirteenth century. In the United States its use to heat homes and other buildings began in the 1750s. Today the major use of coal in this country is to generate electricity. According to the Department of Energy, the United States consumed approximately 620 million short tons (about 562 million metric tons) of coal in 1977.[1]

The nation has enough coal reserves to meet its energy demands for several hundred years, but much of the coal is too deep in the earth to be extracted by conventional mining methods, is of low quality, and contains a high percentage of impurities. Besides these difficulties many other problems must be solved before coal can be considered competitive with oil and gas as an energy source. These problems include pollution, human safety in production, and transportation.

#### Petroleum

The first oil well in America was drilled in Titusville, Pennsylvania, in 1859. That year the country used about 200 gallons (757 litres) of oil a day. In 1977 the United States used about 19 million barrels (over 3 billion litres) daily.[2] Over 40 percent[3] of that oil was imported at prices up 400 percent since 1973.[4] Petroleum is used for transportation, heating, industry, and the generation of electricity.

#### Natural Gas

Found in oil fields, natural gas was considered a waste product for many years and was burned off. (Ironically, it is still burned off in the Middle East, Africa, and many other parts of the world.) Since World War II natural gas has come into widespread use and now heats over half of America's homes and most of its public buildings. It is also used to create electricity and as a raw material in the production of fertilizers.

Today about three-fourths of the nation's energy needs are supplied by petroleum and natural gas, the least abundant fuels. Coal provides only about 19 percent,[5] but its use should increase as mining technology improves. In California oil and gas provide about 92 percent and coal about 3 percent[6] of the total energy used, according to the California Energy Resources Conservation and Development Commission (hereafter referred to as the California Energy Commission). Experts' estimates of U.S. and world fuel reserves vary, but all agree on one thing: Ultimately the world's gas and oil will disappear, leaving coal and other fuels to bear the burden of supporting global energy needs.

#### Hydroelectric Power

The production of hydroelectric energy in the U.S. has doubled in the last 25 years to about 4 percent of the country's total energy needs.[7]

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[1] *Monthly Energy Review*. DOE/EIA-0035/3. Prepared by the Energy Information Administration. Springfield, Va.: U.S. Department of Energy, March, 1978, 30.

[2] Figures derived from *School Energy Crisis: Problems and Solutions*. Produced by Shirley Boes Neill for the American Association of School Administrators. Arlington, Va.: American Association of School Administrators, 1977, pp. 11-12.

[3] *Monthly Energy Review*. DOE/EIA-0035/4. Prepared by the Energy Information Administration. Springfield, Va.: U.S. Department of Energy, April, 1978, 43.

[4] Neill, *School Energy Crisis*, p. 12.

[5] *Monthly Energy Review*. DOE/EIA-0035/1. Prepared by the Energy Information Administration. Springfield, Va.: U.S. Department of Energy, January, 1978, 46.

[6] *Quarterly Fuel and Energy Summary*, Vol. 3, No. 2. Sacramento: California Energy Resources Conservation and Development Commission, Second Quarter, 1977, p. 20.

[7] Harry O. Walker, *Energy: Options and Issues*. Davis: University of California, Davis, March, 1977, p. 81 (syllabus).

Production is not expected to increase substantially, however, because many of the areas that are suitable for hydroelectric development in the U.S. have already been developed. California is more fortunate than the rest of the country. During a wet year about 30 to 40 percent of the state's electric energy comes from hydro sources. One-third of that is imported from the Pacific Northwest. In dry years, or during droughts, the percentage of electricity generated by flowing water decreases, creating a greater demand for fossil fuels.

During October–December, 1977, California elementary and secondary schools used about 3 billion cubic feet (85 million cubic metres) of natural gas and about 607 million kilowatt-hours of electricity, for a total cost for the three-month period of $35 million, or approximately $7.77 per student. During the same period elementary and secondary schools used 0.2 percent of the natural gas and 0.4 percent of the electricity consumed in California.[8]

[8]These figures are based on data supplied by the California Energy Commission and the Bureau of School Apportionments and Reports, California State Department of Education.

## "New" Fuels

Relatively "new" fuels or sources of energy include solar energy, geothermal energy, and nuclear energy.

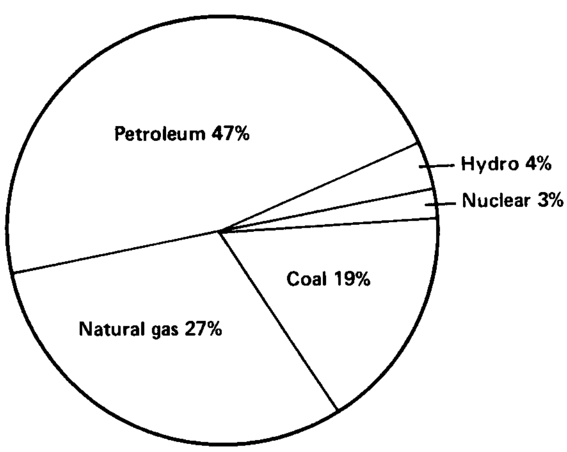
### Solar Energy

Solar energy is a reality today in several California schools. It is available almost everywhere, is nonpolluting, and is virtually inexhaustible. In one year the radiation that reaches the surface of the continental United States exceeds the total amount of fossil energy that will ever be extracted in this country.[9] Even with a low energy-conversion efficiency of 5 percent, the nation's total yearly energy needs could be met with the sunlight that falls in a year on 4 percent of the continental land area.[10] The California Energy Commission, in its seven-volume 1977 biennial report, *California Energy Trends and Choices,* estimates that the use of solar energy in buildings could realistically

[9]Edmund Faltermayer, "Solar Energy Is Here, but It's Not Yet Utopia," *Fortune* (February, 1976), 103.

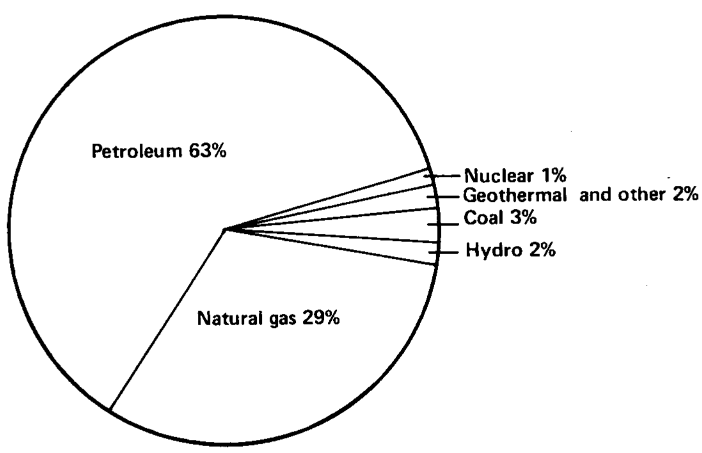
[10]*Schoolhouse,* No. 26 (January, 1977), 2 (newsletter published by Educational Facilities Laboratories, New York).

**Energy Use Breakdown**




**United States, 1976**

Source: Derived from figures in *Monthly Energy Review.* DOE/EIA-0035/1. Prepared by the Energy Information Administration. Springfield, Va.: U.S. Department of Energy, January, 1978.



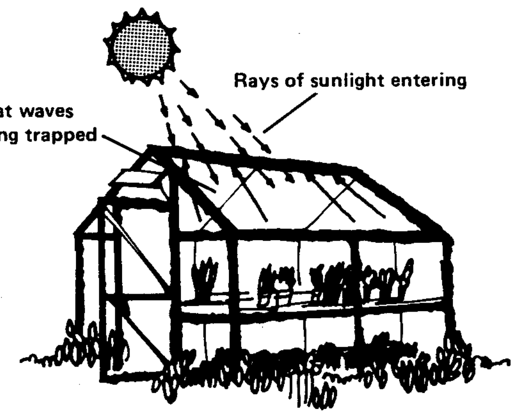

**California, 1976-77**

Source: Derived from figures in *Quarterly Fuel and Energy Summary,* Vol. 3, No. 2. Sacramento: California Energy Resources Conservation and Development Commission, Second quarter, 1977.

supply 8 to 12 percent of California's total energy needs.[11]

But solar potential is often oversold. Solar energy is low in concentration, and it is undependable—sunlight can disappear just when it is needed the most. Solar energy is also relatively expensive to collect at this time.

Solar energy systems are based on the principle that anything exposed to the sun absorbs its heat. Heat absorption is only part of the reason that the steering wheel and other parts of a car become so hot on a hot day, however. Glass has a specific property that lets it transmit shorter wavelength visible rays of sunlight but not longer wavelength invisible heat waves. Sunlight passes through the car windows, is absorbed by the steering wheel and other parts of the car, and is changed to heat waves. The heat waves cannot pass through the windows and are "trapped" inside the car, raising the inside temperature. This principle is utilized most efficiently in an ordinary greenhouse and has become known as the "greenhouse effect." The greenhouse effect can be used to heat a school and to heat water for its hot water system and swimming pool. Very hot water can also be used to help cool a school in much the same way that an old-time gas refrigerator cooled food.




**The "greenhouse effect" can be used to heat a school and to heat water for its hot water system and swimming pool.**

Basically, two types of systems can be used to convert solar energy to usable heat energy: active systems and passive systems. (Converting solar energy to electricity is discussed under "Fuels of the Future," p. 10.) An active solar system uses

[11] *California Energy Trends and Choices,* Vol. 5. Prepared by the Office of Energy Systems Integration. Sacramento: California Energy Resources Conservation and Development Commission, 1977, p. 19.

George Lyons Photo courtesy of Robert E. Des Lauriers, Architect, La Mesa

**Solar panels at Green Elementary School, San Diego City Unified School District, provide space heating for one six-room classroom building.**

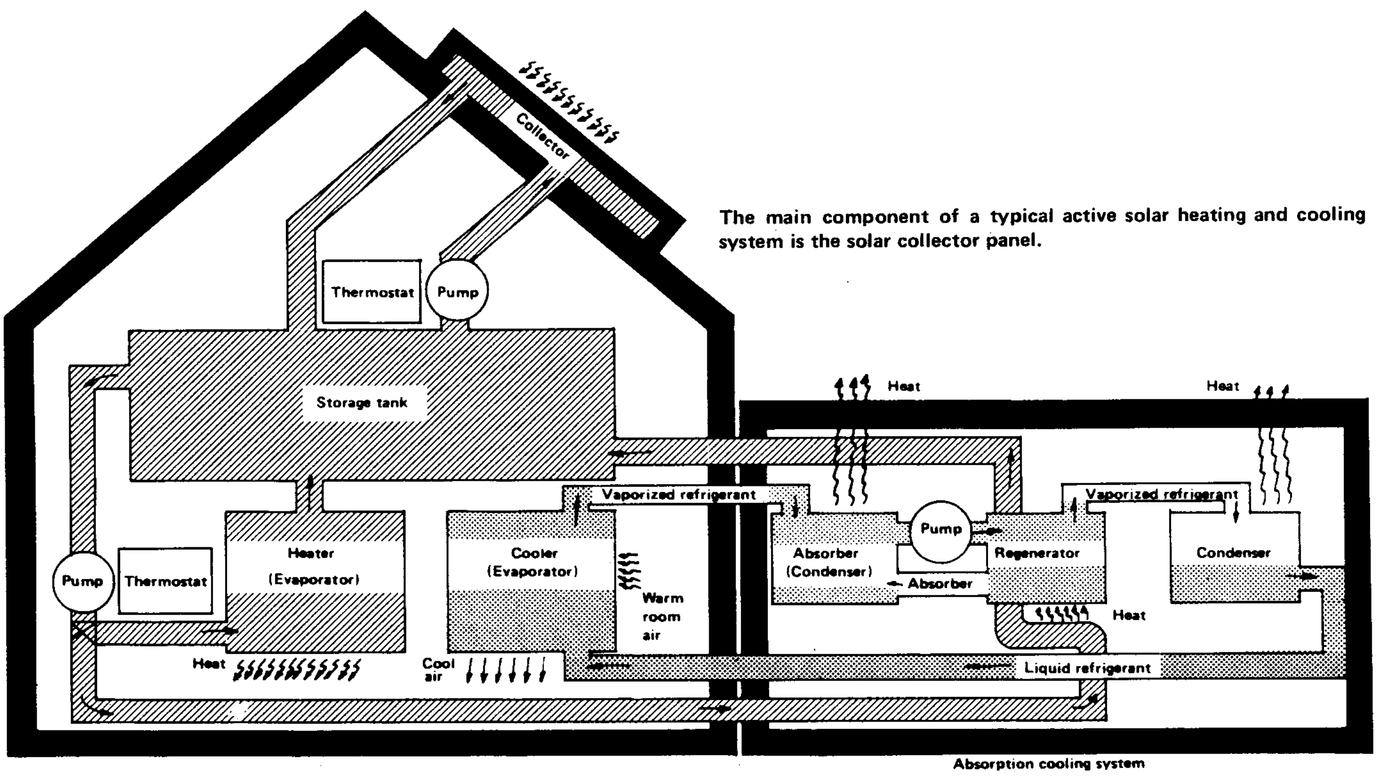
mechanical devices—pumps, fans, or motors—to move the sun's heat to the interior of a building or to storage areas. A passive system uses natural means—gravity, convection, or radiation—to do the same thing.

*Active systems.* The main component of a typical active system is the solar collector panel, which consists of a heat absorber plate that is usually made of metal. The plate is coated black to increase absorption and reduce radiation of the sun's energy, and its underside is insulated to prevent heat from escaping. One or more glass or plastic cover plates trap heat within the collector (the greenhouse effect). Either water or air is circulated through the panels, carrying heat to storage and distribution equipment. On sunny days the temperature of the absorber plate can reach well over 200° F. (93° C.). Not all of the energy reaching the collector is transferred to the air or water, however. Collectors operate at an effectiveness level of from 30 to 50 percent.[12] The rest of the heat energy is lost to the atmosphere.

[12] *Solar Energy for Heating and Cooling.* EOM-817R. Washington: Energy Research and Development Administration, 1977 (brochure).

So that as much sunlight as possible is received, banks or arrays of collector panels are normally mounted on a south-facing roof and slanted at an angle that places them perpendicular to the sun's rays. Since the winter sun is lower in the sky than the summer sun, the angle of tilt of solar panels will depend upon whether the greatest need is to maximize winter heating or summer cooling capabilities. Large water tanks or rock beds (for air systems) are used to store the heat until it is needed and are usually placed underground for added insulation. When needed, solar heat is transferred to the building's heating system or water heating equipment and put to use. Many people prefer hot air and rock storage systems to water systems since problems such as possible freezing of pipes are avoided.

*Passive systems.* The simplest type of passive system uses the building itself as both system and storage. The building "soaks" up the winter sun through large south-facing single- or double-glazed windows. The sun heats the interior directly during the day, and massive walls and ceilings (up to 1 foot [0.3048 metre] thick) made of dense, heat-absorbing materials such as masonry, adobe, con-



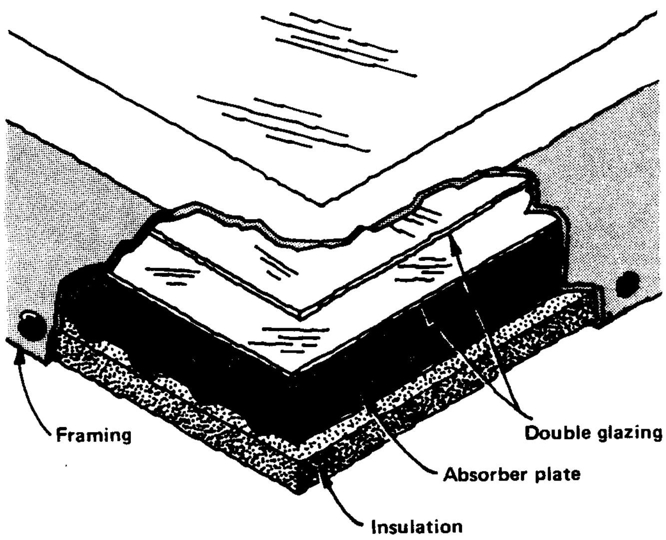

The main component of a typical active solar heating and cooling system is the solar collector panel.

Adapted from *Solar Energy for Heating and Cooling.* EDM-817R (1-77). Washington: Energy Research and Development Administration, 1977.

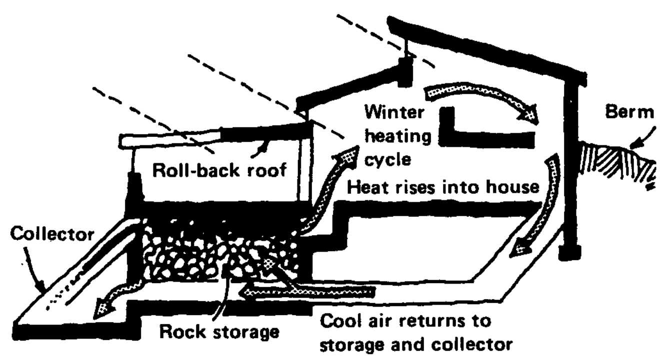
crete, or stone act as heat sinks, radiating stored heat back into the rooms after dark. Summer heat is minimized as much as possible through the use of windows shaded by deciduous trees, overhangs, heavy drapes, or other means; and roofs are light colored to reflect rather than absorb the sun's rays.

A house with a passive solar heating system may be partially buried in an earth berm to take advantage of the natural insulation of the earth; or it may include a greenhouse, a glass-enclosed room designed to collect heat, not to grow plants. By day the greenhouse traps heat; at night it is sealed off from the rest of the building to keep heat stored inside the house from escaping through the glass. The addition of plants helps to provide humidity, making lower temperatures more livable. In summer the glass is shaded, and vents at the top are opened to prevent overheating.

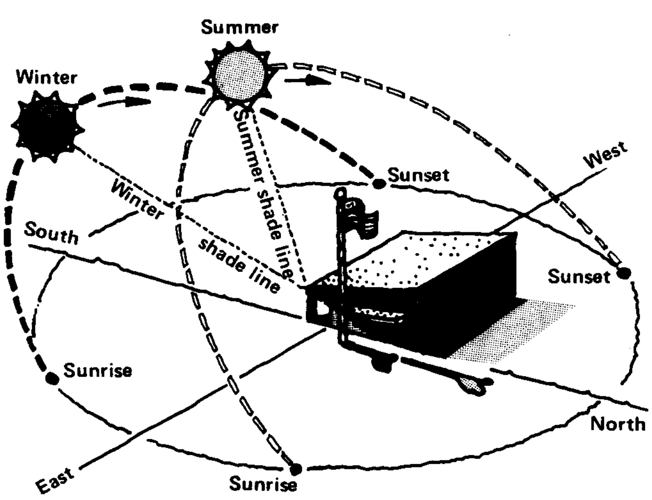
The Trombe wall, invented by Felix Trombe, is a passive system using building mass and the greenhouse effect. The system consists of a black concrete south wall with high and low openings and a double-glazed outer wall. On a winter's day the sun warms the room by convection; at night the room is warmed by delayed radiation as the concrete heat sink gives up its collected warmth. In summer the sun is blocked by an overhang, and vents are opened to create a "chimney effect" to channel hot air outdoors.




A typical solar panel is made up of (1) framing; (2) double glazing; (3) absorber plate; and (4) insulation.




A passive solar system uses natural means—gravity, convection, or radiation—to move the sun's heat to the interior of a building or to storage areas.



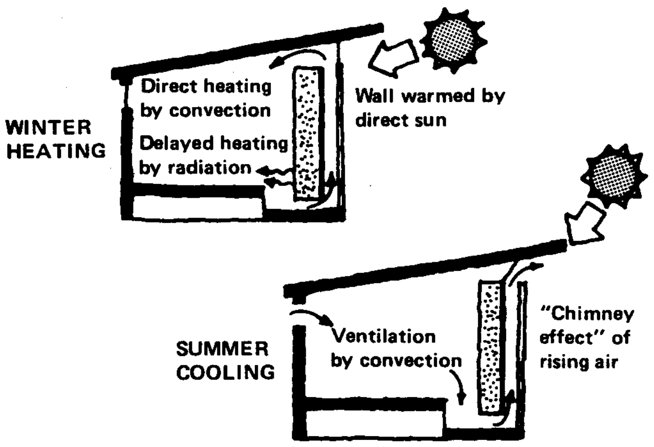

The winter sun is lower in the sky than the summer sun. Thus, the angle of tilt of solar panels to be added to this school would depend upon whether the greatest need is to maximize winter heating or summer cooling capabilities.

A more complicated passive system uses solar panels and transmits heated air or water by gravity, convection, radiation, and conduction directly to the building or into a storage system and then into the building at a later time. Many of these systems can also work "in reverse" to cool a building by giving off heat collected during the day to the cool night air.

With either an active or passive system, a back-up heating system is usually necessary to provide heat during extended cold and cloudy periods.

A list of school solar projects that are operational, under construction, or in the planning stages is provided in Appendix A. A list of other energy responsive school projects is included in Appendix B.

*Domestic water heating.* Solar energy has been used extensively for many years to heat water in homes in Australia, Israel, Japan, and Florida, where fuel costs are high and the weather is sunny most of the year. In some cases the heating of water may be part of a space-heating system.




**The Trombe wall is a passive solar system that uses the greenhouse effect to collect the sun's heat and a black concrete wall as a heat sink.**

Water that has been heated by the sun in the solar collector may be run directly into the hot water storage tank or through a heat exchanger coil in the tank to heat the stored water. When the water cannot be heated to a usable temperature in the solar hot water storage tank, a back-up heater is used.

*Swimming pool heating.* Swimming pool heating is an ideal application of solar energy. Expensive heat storage equipment is not needed because the pool provides its own storage for solar heat and requires relatively low-temperature water. If the pool is in direct sunlight, the sun is already helping to raise the water temperature.

In the most common system, a large flow of filtered pool water is pumped into the collector panels, where the heat from the sun's rays is transferred from the warm panel to the water, raising the water temperature a few degrees. The heated water is then returned to the pool. With constant circulation through the panels, the pool water gradually reaches the desired temperature.

As with space heating, a conventional heating system may still be required as a back-up system to achieve the desired pool water temperature on cloudy days.

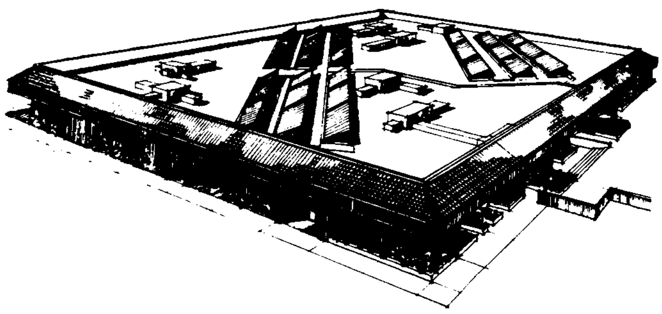
*Solar cooling.* Because of the widespread use of air conditioning in the United States, much attention has been focused on using solar energy for cooling as well as heating. Solar cooling uses absorption refrigeration equipment of the type used in gas-burning refrigerators and air conditioners. The solar heat simply substitutes for the gas flame. Cooling requires higher temperatures than heating—190° to 200° F. (88° to 93° C.)—

**Canyon Elementary School, Canyon Union Elementary School District, Lakehead, utilizes passive cooling techniques. During hot weather vents are opened at night to allow cool air to enter. In the morning vents are closed. Body heat, heat from lights, and sunshine gradually heat the interior air, which rises. Vents at the roof peak are then opened to allow the warm air to escape.**

and thus requires more sophisticated solar panels. The biggest advantage of solar air conditioning is that it works best when it is needed the most—when the sun's heat is greatest during the day. Unfortunately, for most schools solar cooling systems are extremely expensive in their current forms.

### Geothermal Energy

Like a huge furnace the earth's interior contains tremendous amounts of heat. This is geothermal energy, which can be found in several types of theoretically tappable reservoirs: hot water, dry steam, hot dry rock, and geopressured water, a potential source of mechanical (hydraulic) energy. According to the California Energy Commission, the ultimate heat source in the core of the earth will not be depleted in the geologically foreseeable future, but the heat content or steam pressure of a particular reservoir may be depleted by exploitation within a few decades.



Sketch courtesy of Porter, Jensen, Hansen, Manzagol, Architects, Santa Clara

**Solar panels on the roof of El Camino Real Elementary School, Irvine Unified School District, are used in cooling the building's interior.**

In most parts of the world, the geothermal energy reservoirs are too deep to be reached with existing drilling technology, but in some areas large heat sources occur close to the surface and can be tapped. Geothermal energy is used to generate electricity in many countries, including Iceland, Italy, Japan, Mexico, the Soviet Union, and the United States. In this country the major geothermal power plants are located in northern California at a natural steam field known as The Geysers. A total of 106 geothermal systems have been identified in the western states by the United States Geological Survey. Homes in Boise, Idaho, and Klamath Falls, Oregon, and a church in Susanville, California, get their heat from hot water wells. A major problem of geothermal energy is the corrosivity or impurity of many of the known existing hot water sources.

### Nuclear Fission

In 1977 nuclear power plants produced about 3 percent of the nation's total energy. Nuclear fission is seen by many as one of the major solutions to America's energy dilemma. Problems do exist, however, including limited supplies of uranium, nuclear fission's base material, and technological roadblocks. And, of course, many environmentalists have waged vigorous struggles against the expansion of nuclear power facilities.

## Fuels of the Future

Most of America's potential energy sources are now only in the idea or laboratory stages and are not expected to be utilized for many years. Some of them are discussed below.

### Wind Power

For centuries wind power contributed substantially to the world's energy supply. In America windmills were used to pump water, saw wood, and generate electrical power for over 50 years; from 1880 to 1930 over 6 million windmills generated electric power in the West. Cheap fuels were eventually determined to be better sources of energy, but by 1950 about 50,000 wind-powered electricity generators were still in operation around the country. By the year 2000 practical wind-driven power plants could generate enough electricity to meet nearly 20 percent of the United States' electrical needs.[13] The California Energy Commission estimates that wind power could be used to meet 9 to 15 percent of the state's electricity requirements by 1995.[14] Advances in aerodynamic design and engineering and improvements in energy storage will be necessary, however, before such production is possible. The California Energy Commission encourages science classes to help locate areas of usable wind energy in the state and report them to the commission for further investigation. For more information write to the Wind Energy Program, California Energy Commission, 1111 Howe Avenue, Sacramento, CA 95825.

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[13] *Energy Conservation: Understanding and Activities for Young People.* FEA/D-75/264. Washington: Federal Energy Administration, 1975, p. 5.

[14] *California Energy Trends and Choices,* Vol. 5, p. 19.

### Oil Shale

The "pressure cooking" of shale to yield oil is expensive. It also presents environmental problems. An acceptable procedure for rendering oil in this manner will not be available until the late 1980s at the earliest. Perhaps as much as 100 billion barrels (about 16 trillion litres) of oil are accessible in deposits in Colorado, Wyoming, and Utah.[15]

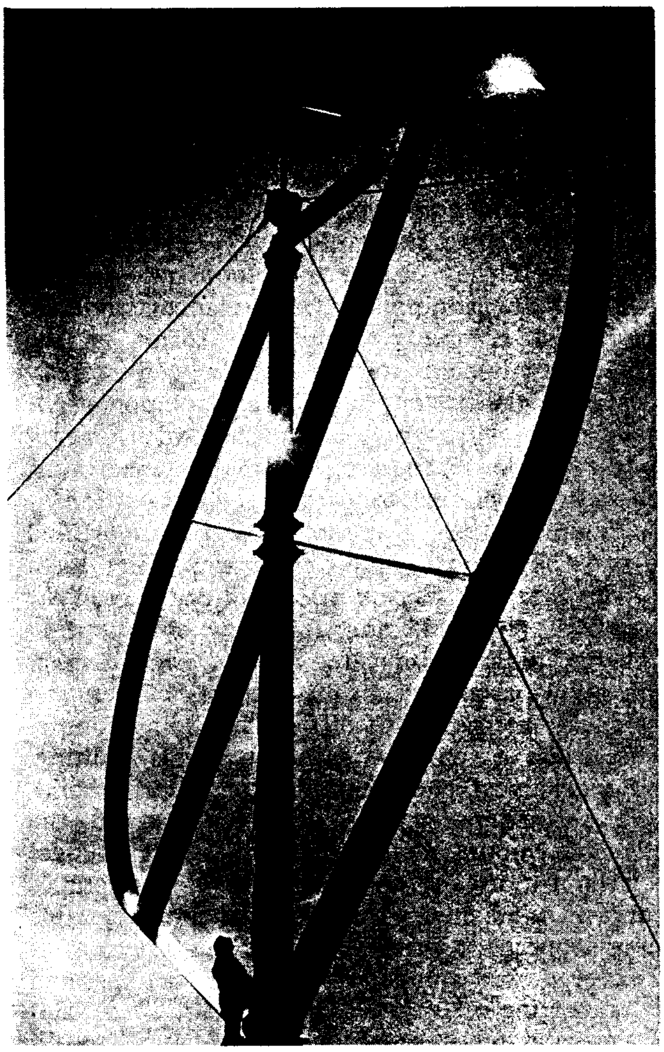

Photo courtesy of Sandia Laboratories, Albuquerque, New Mexico

**By the year 2000 wind-driven power plants such as this one at the U.S. Department of Energy's Sandia Laboratories in Albuquerque, New Mexico, could generate enough electricity to meet nearly 20 percent of the United States' electrical needs.**

### Solar Electricity

Solar electricity can be produced by (1) solar thermal conversion; and (2) photovoltaic conversion.

*Solar thermal conversion.* As long ago as 1913, a power plant in Egypt used the sun's heat to generate electricity. Steam produced by solar heat powered a 50-horsepower steam engine along the banks of the Nile River. In the U.S. research began recently on solar thermal conversion at the Department of Energy's Sandia Laboratories in New Mexico, and a pilot plant is expected to begin operation in the next decade.

*Photovoltaic conversion.* The conversion of sunlight directly into electricity in solar cells has supplied most of the electricity for a variety of space vehicles, including the Apollo spacecrafts. The costs of photovoltaic conversion (hundreds of dollars per kilowatt) are currently prohibitive. If the Department of Energy can meet its goal of reducing the price of solar cells to $0.50 a peak watt by the mid-1980s, photovoltaic conversion would be able to "compete" with fossil fuels and nuclear plants as an energy source in this country.

### Other Possibilities

Research is being done on the creation of artificial fuels by hydrogenation (heating solid wastes under high pressure), pyrolysis (heating wastes at high temperatures in an oxygen-free environment), and natural fermentation. These fuels, plus potential energy from tidal action, ocean thermal gradients, hydrogen, breeder reactors, and nuclear fusion, may well be the fuels of the future. Time is needed, however, to overcome technological, environmental, and economic barriers. Many people believe that at the rate fossil fuels are disappearing, time is running out.

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[15] *The United States Energy Research and Development Administration.* EDM-055. U.S. Energy Research and Development Administration, 1975, p. 4.

# Factors to Consider in Planning a New Facility

Tomorrow's schools must be built with energy conservation in mind. New energy conservation standards and diminishing supplies of traditional energy sources make this imperative.

The following sections contain information about the new energy conservation standards for new nonresidential buildings in California and suggestions for school districts and architects to consider in planning new school facilities. Those involved in such planning are cautioned, however, not to use some conservation methods in such a way that they neutralize the effects of other measures. For example, trees that are used to provide shade should not be planted where they will prevent sunlight from reaching a solar collector.

## Energy Conservation Standards

On June 30, 1977, the California Energy Commission adopted energy conservation standards for new nonresidential buildings. Upon approval by the State Building Standards Commission, the standards were incorporated into the California Administrative Code, Title 24, Building Standards. In October, 1977, the California Energy Commission published *Energy Conservation Design Manual for New Nonresidential Buildings* (hereafter referred to as the *Design Manual*) to assist those who must comply with and enforce the standards and to "encourage the design, construction and operation of energy efficient buildings in California." The initial analysis of the standards indicates that compliance can be achieved with current school construction practices. It is anticipated, therefore, that the standards will be made much more rigid as time passes.

The new standards contain the legal requirements for the energy efficiency of the building skin, or "envelope"; heating, ventilating, and air conditioning (HVAC) systems and equipment; lighting systems; and water-heating systems. The *Design Manual* contains descriptions of the procedures, calculations, and documentation that must be completed to demonstrate compliance with the standards and includes copies of recommended compliance forms. Also included are recommended conservation measures designed to reduce energy consumption even further. Most of these recommendations are included in this publication.

### Compliance Procedures

Architects and engineers can provide for compliance with the standards in two ways. They may choose to show compliance with either (1) component performance standards; or (2) energy budget standards. If they choose to demonstrate compliance with the component performance standards, they must complete compliance forms on the various components of the building and satisfy energy efficiency criteria for each component. If they choose to show compliance with energy budget standards, the architect and engineer must calculate the annual total energy consumption of the building, using a computer program certified by the California Energy Commission. They must demonstrate that consumption will not exceed the maximum allowable annual energy consumption ("energy budget") indicated in the *Design Manual.* This allows architects to make trade-offs between the energy efficiency of different building components, such as window space, materials, lighting, and mechanical equipment, as long as the building's entire energy use does not exceed the allowable amount. Credit against the energy budget is given for use of nondepletable energy sources (solar or wind energy). The use of nondepletable energy sources to provide more than 40 percent of the energy used annually for heating, cooling, and water heating or to provide more than 20 percent of the total energy used annually is considered to represent compliance. Special documentation, described in the *Design Manual,* is required, however. In the majority of schools, compliance with component performance standards will probably be the most appropriate and simplest method of complying with the standards.

A review of a number of existing schools of various types, sizes, materials, locations, configurations, and grade levels by Bureau of School Facilities Planning staff indicated that the standards were met in only one instance. However, all the schools easily would have met the requirements if they had included more wall or roof insulation.

#### Enforcement Dates

For public buildings, including schools, with 10,000 square feet (929 square metres) or less of conditioned floor space, the enforcement date for the energy conservation standards was July 1, 1978. After that date building permits will not be issued for any public building that cannot meet the standards. Compliance documentation is to be submitted to the appropriate building code enforcement agency, which will verify it before issuing a permit.

For public buildings, including schools, with more than 10,000 square feet (more than 929 square metres) of conditioned floor space, the enforcement date has been extended to January 1, 1979. Before January 1, 1979, the California Energy Commission will determine the agency or agencies responsible for review and approval of compliance documentation for schools and other public buildings and will inform school districts, public officials, local contractors, and architects of the procedures to follow.

#### Increases in Fees and Construction Costs

Compliance with the energy conservation standards will increase architects' and engineers' fees for school buildings. In the opinion of some architects and engineers, the fees will probably increase by an average of 0.3 percent of the cost of the building. Construction costs are expected to increase by at least 3 percent. Plan-check and inspection fees for school buildings will also increase to some degree.

#### Delays

Whether or not the energy conservation standards will cause delays in building design and construction is not known at this time. Some additional time will be required, however, for architects and engineers to complete the required compliance forms or to obtain a computer analysis and for the designated authority to review the forms or analysis and issue building permits. Since the concept of energy-efficient building standards is new, some confusion or misunderstandings may occur. In addition, the forms and standards have not been finalized. Delays may occur also in obtaining equipment and materials that meet the standards. For example, insulative building materials will have to be certified by an independent testing laboratory, which may lead to some delays in obtaining tested and approved materials.

#### Procedures for Ordering the *Design Manual*

Copies of the *Design Manual* may be ordered from the California Energy Commission at the following address:

California Energy Commission
Publications Unit–*Design Manual*
1111 Howe Avenue
Sacramento, CA 95825

The cost of the manual is $10, plus sales tax for California residents, and postage.

### Life-Cycle Costing

During the life of a school facility, operating and maintenance costs (including energy costs) are three to four times the initial cost of the building.[1] That is why more and more school officials and boards of education are becoming aware of the folly of awarding construction or equipment contracts on the basis of initial costs alone and are considering long-range operating and maintenance costs as well. Life-cycle costing can avoid the false economy achieved by cutting first-costs only to end up with a building that during its lifetime is extravagantly expensive in terms of both energy and dollars.

Some of the data needed to do a life-cycle cost analysis are the following:

1. Annual fixed charges, based on a capital recovery period of perhaps 20 years and including the interest charge
2. Annual energy and fuel charge, based on different energy sources under consideration and the fuel use rate of different equipment
3. Annual maintenance costs
4. Annual replacement costs for equipment

The National Bureau of Standards has also developed life-cycle costing techniques for evaluating building designs for energy conservation. Among the factors considered are first-cost, estimated energy savings, cost of capital (interest), inflation, increased energy costs, tax credits, maintenance and operation, insurance, and salvage costs. Because of the complexity of these calculations and the assumptions that must be made about the data, that agency strongly advises that the analysis be performed by a qualified economist.

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[1]Richard Rittelmann, "Design New Buildings to Save Energy—and Money," *American School & University,* Vol. 46 (January, 1974), 25.

Further information on life-cycle costing can be found in the *Design Manual; The Economy of Energy Conservation in Educational Facilities* (New York: Educational Facilities Laboratories, 1973); and "Energy Conservation Through Life-Cycle Costing," in the February, 1977, issue of the *Journal of Architectural Education.*

### Site Selection

A major factor in selecting a building site from several alternatives should be energy conservation. Climate affects different sites and building types with varying severity, depending on location, topography, prevailing winds, trees and other vegetation, and surrounding buildings. This results in varying energy requirements, even for buildings in different parts of the same city. An architect can help school boards determine the energy advantages and disadvantages of the microclimate of each site and adapt the building design to the microclimate of the site chosen.

### Orientation

The orientation of the building on the site will also affect energy consumption. A rectangular building absorbs less solar heat (and thus needs less energy for air conditioning) if its long dimension is aligned in an east-west rather than in a north-south direction. (East and west walls are baked longer and more intensely by the sun than north, or even south, walls.) A building incorporating solar heating or cooling should be oriented so that the collector panels face south to receive as much sunlight as possible. A building that will make use of cooling breezes should be placed where air can flow through open windows, louvers, or vents. Since ground temperature is fairly constant below the frost line, the *Design Manual* includes recommendations for considering the feasibility of building into the slope on sloping sites or using earth berms to reduce heat loss through the walls during the heating season and to provide added cooling during the cooling season. This may or may not be applicable to schools, however, because of high air conditioning loads even in winter and the loss of breezes for natural ventilation. (Those interested in a "berm" school may wish to investigate Birchwood Elementary and Brooktree Elementary schools [Berryessa Union Elementary School District, San Jose] and Bernal Intermediate, Blossom Valley Elementary, and Oak Ridge Elementary schools [Oak Grove Elementary School District, San Jose]. Fremont Elementary School in Santa Ana [Santa Ana Unified School District], depressed 5 feet [1.524 metres] below ground level, is an example of another design using the insulating quality of the earth.)

### Building Shape

The shape of a building plays a basic role in determining its energy requirements. Since heat is gained and lost through the walls and roof, minimizing these surface areas will help reduce energy consumption. Given equal gross floor area, a spherical or round building has less surface area in relation to interior space (volume) than any other building configuration. A square building has less surface than a rectangular one of equal floor space. Three-story, double-loaded classroom corridor wings have 35 percent less surface area than single-story buildings of equal volume.[2] Compact buildings also provide for reduced air conditioning,

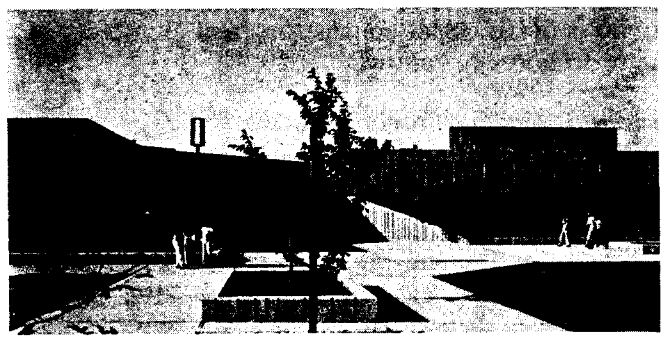
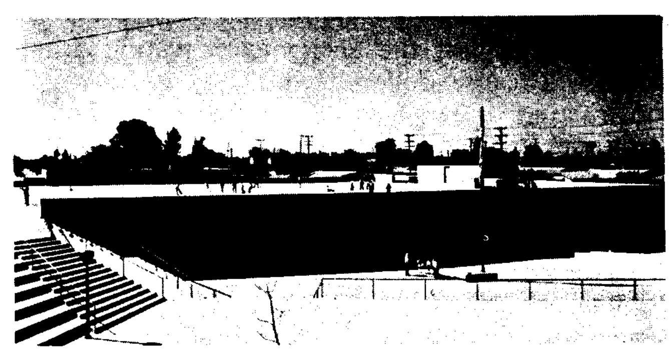


Photo courtesy of Porter, Jensen, Hansen, Manzagol, Architects, Santa Clara

**At Brooktree Elementary School, Berryessa Union Elementary School District, San Jose, earth berms are used to insulate the school from outside temperatures.**



Carlos von Frankenberg Photo courtesy of Allen and Miller, Architects, Santa Ana

**Fremont Elementary School, Santa Ana Unified School District, is depressed 5 feet (1.524 metres) below ground level to take advantage of the earth's insulating qualities.**

[2] *The Economy of Energy Conservation in Educational Facilities.* Prepared by Educational Facilities Laboratories. New York: Educational Facilities Laboratories, 1973, p. 49.

plumbing, and electrical costs since pipe, duct, and conduit runs are short. (Estancia High School in Costa Mesa [Newport-Mesa Unified School District, Newport Beach] is an excellent example of a large, yet compact, energy-efficient school.) The natural ventilation and lighting potential of a sprawling single-story building may, however, offset its additional land and construction costs and thermal transmission through the surface.

A review by Bureau of School Facilities Planning staff of a number of existing schools of various types, sizes, materials, locations, configurations, and grade levels indicated no special energy conservation advantage for any particular school configuration–campus, cluster, or finger plan. More research is necessary; however, it is doubtful that one specific design solution will be found to be applicable for all parts of the state. An engineer can advise the architect on the energy trade-offs of different building shapes and features. The *Design Manual* includes a recommendation that architect and engineer work together on the building design from its conception. Also recommended in the *Design Manual* is the use of self-shading building shapes and minimal west-facing wall exposures in those parts of California in which the reduction of summer cooling loads is desirable. External shading devices, such as canopies, fins, metal grillework, and projecting mullions, are more effective than internal shading with shades, venetian blinds, or drapes.

### Landscaping

In the *Design Manual* planting deciduous trees near south walls is recommended. They shade and cool the building in the summer; in the winter when they drop their leaves, sunshine is permitted to strike the building and pass through windows. Shade trees should be transplanted in as large a size as practicable; a fast-growing five-year-old tree needs only five more years to grow to a size that allows it to provide 80 percent of its full shade potential.[3] Evergreens planted near northern walls act as windbreaks. If the building is to be naturally ventilated to some extent, care must be taken not to plant trees that will block cool breezes. Suggestions in the *Design Manual* include minimizing pavement, particularly dark-colored pavement, which absorbs a great deal of heat and radiates it to buildings. Fountains, ponds, and sprays can be both attractive and useful. A significant amount of free precooling can be obtained if the building intake for ventilating air is located near water.

### Color Selection

In the selection of building colors, attention must be given to roofs and walls and ceilings.

#### Roofs

The darker a sun-exposed surface, the more heat it absorbs. A dark roof can absorb tremendous amounts of heat. For example, on a sunny day during which the air temperature is 95° F. (35° C.), the surface temperature of a black roof will be 190° F. (88° C.); the surface temperature of a dark gray roof will be 175° F. (79° C.); the surface temperature of a light gray roof will be 160° F. (71° C.); and the surface temperature of a white roof will be 140° F. (60° C.).[4] Absorbed heat radiates into the building, causing high air conditioning loads; and, due to expansion, the roofing materials deteriorate. A light-colored roof reflects much of the sunlight that hits it and will keep cooler and last longer than a dark-colored roof. A dark roof may be desirable in areas where heating is the major consideration.

#### Walls and Ceilings

Light-reflective interior finishes can add an equivalent of 30 footcandles of illumination to a space. In a typical classroom this would permit a 30 to 40 percent reduction in artificial lighting levels.[5] Light-colored wall and ceiling surfaces should be kept clean–dirt also reduces illumination.

### Insulation

The greater the difference between the temperatures inside and outside a building, the faster heat is lost or gained through the walls, roof, and floor. The basic function of insulation is to block heat loss in the cold winter months and heat gain in summer. Insulation performance, or "thermal resistance value," is measured in terms of R-numbers. The higher the R-number, the more the insulation will prevent heat flow. Although the energy conservation standards do not include specific R-number requirements for insulation used in nonresidential buildings in California, to meet overall conserva-

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[3]Victor Olgyay, *Design with Climate.* Princeton, N.J.: Princeton University Press, 1963, p. 74.

[4]C. W. Griffin, Jr., *Manual of Built-up Roof Systems.* New York: McGraw-Hill Book Company, 1970, p. 83.

[5]C. W. Griffin, Jr., *Energy Conservation in Buildings: Techniques for Economical Design.* Washington: The Construction Specifications Institute, 1974, p. 45.

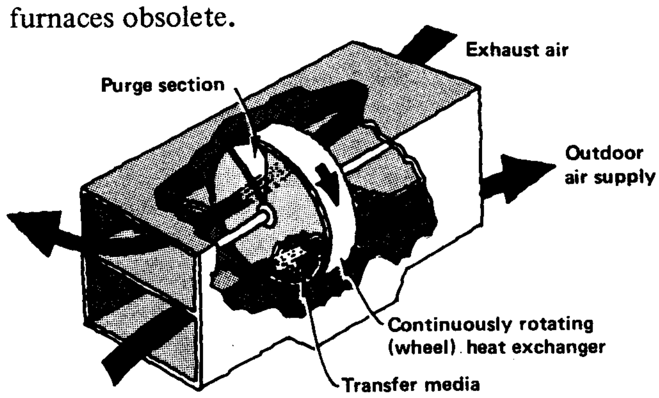
tion criteria, most builders must boost the R-values of the insulating material they install. A well-insulated school building wastes fewer energy dollars by reducing heat loss or gain through the walls, roof, and floor. To ensure the quality of insulation sold or installed in California, the California Energy Commission was, pursuant to Senate Bill 459 (Chapter 1006, Statutes of 1977), to adopt insulation standards by July 1, 1978. The standards are to go into effect one year after their adoption.

### Glazing

Glazing–glass, plastic, or other transparent material set into a window frame or placed over solar collectors–is extremely ineffective in keeping heat in or out of a building. Double-glazed windows, those with two panes enclosing an air space, roughly double the thermal resistance of single-glazed windows. Even so, they are not as effective as a well-insulated wall in preventing thermal transmission. Many buildings have more windows than they need for natural light, ventilation, or view; and their heating and cooling systems waste energy combatting drafts or heat that has infiltrated the building. Reducing the number and size of windows to the necessary minimum should ease the burdens on the heating, ventilating, and air conditioning system. The engineer can calculate infiltration and, along with the architect, will advise the school board on the energy-efficiency of single- or double-glazing, window size and number, best orientation of windows, and use of heat-absorbing or reflective glass.

### Heat Recovery Systems

Schools produce a great deal of waste heat from kitchens, lights, kilns, boilers, computers, and people. (The collective body heat of 30 quiet students in a classroom could release 14,000 Btu to room air each hour.[6]) Much of this heat is simply exhausted, and lost, to the outdoors; but in many schools enough remains inside the building to require air conditioning, even in winter. Removing waste thermal energy from where it is not wanted and reusing it where it is wanted can save gas or electricity–and dollars. Recaptured heat can be used immediately to heat or cool rooms or heat water, or it can be stored for later use. Mechanical heat recovery systems such as the rotary heat wheel or heat pump can reclaim as much as 80 percent of used heat and pay for themselves in energy savings in only a few years.[7] As an added bonus removing heat from light fixtures increases luminaire performance. For example, a 40-watt fluorescent lamp operating in 77° F. (25° C.) air produces 14 percent more light than the same lamp operating in 100° F. (38° C.) air.[8] Efficient heat recovery systems and adequate heat storage areas for school buildings could, in time, make active solar heating systems unnecessary and traditional furnaces obsolete.




Mechanical heat recovery systems such as the rotary heat wheel can reclaim up to 80 percent of used heat. The wheel rotates slowly between the exhaust air stream and the incoming air stream, transferring heat from one to the other.

### Solar Energy

Passive solar energy systems can be effective in schools and should be considered. Active solar energy also seems well-suited to school use. School energy demands are at their peak during daylight hours, when sunlight is available. Schools have especially large hot water needs for showers and kitchens; and solar heat could be used to meet or partially meet these needs. At the very least, solar heating should be considered for swimming pools, since gas-heated pools waste a great deal of energy and are the first to be regulated when gas supplies are low.

First-costs for active solar energy systems are admittedly higher than those for conventional energy systems, but life-cycle costing may show solar systems to be more economical in the long run. Solar energy firms claim that maintenance is minimal, and sunshine is free. Unfortunately, solar technology is too new for those involved to make

[6]"Will Children's Learning Be Stunted and Teachers Irked by Low School Temperatures?" *American School Board Journal*, Vol. 161 (January, 1974), 34.

[7]Ed Stephan, "How to Cut Your District's Fuel Use by 25%–Right Now," *American School Board Journal*, Vol. 161 (January, 1974), 46.

[8]*The Economy of Energy Conservation in Educational Facilities*, p. 42.

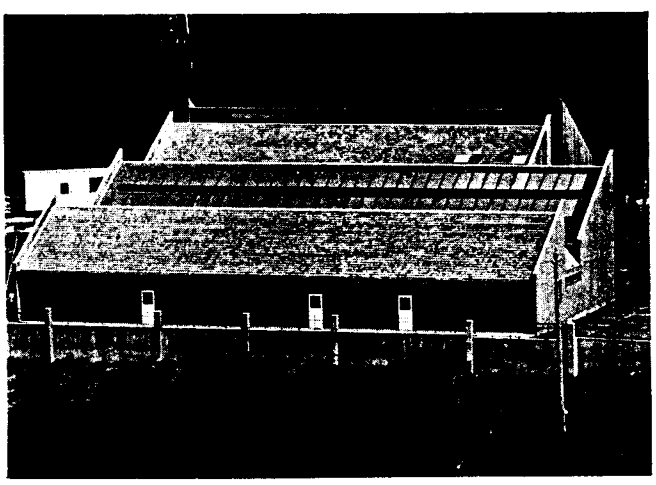
accurate predictions about maintenance and equipment life. Another maintenance factor that no one can predict is vandalism. Solar panels contain glass and other fragile materials that vandals may find appealing. However, an informal Bureau of School Facilities Planning survey of 12 California schools with operating solar systems revealed only two instances of vandalism of the panels.

Grant monies for energy conservation building and "rehabilitation" programs, including solar installations, become available from time to time through the California Energy Commission or the federal Department of Energy. Because application procedures and funds available change, interested districts should keep in contact with the above agencies or the Bureau of School Facilities Planning for current information.

If solar energy does not seem economically feasible now for certain districts, consideration should be given to installing heating and plumbing system connections to which solar systems may be added in the future. Space for solar collectors and heat storage tanks should also be provided.

### Vestibules

Large quantities of heat flow through open doors, both in and out, adding to the burdens upon the heating, ventilating, and air conditioning system. Sheltered entryways and double sets of doors enclosing unheated air-lock vestibules can substantially reduce temperature losses by infiltration, especially in areas with extreme temperature or weather conditions, such as Lake Tahoe or Palm Springs.



**Upon completion of the facility, solar panels will help meet heating needs at North County Development Center in Oakland. The center will be maintained by the Office of the Alameda County Superintendent of Schools.**

### Task Lighting

Task lighting—lighting each area of a room in accordance with the tasks to be performed in that particular area—can help reduce the need for electricity and improve overall lighting quality. For example, while it is desirable to illuminate a classroom in a uniform manner for normal use, task lighting provided at the teacher's work station may substantially reduce energy consumption for those before and after classroom hours when the teacher is alone in the room. Task lighting may also be appropriate for classrooms with play and other nonreading areas, and it should be used in rooms with study carrels. Before a task lighting system is designed, each task must be analyzed thoroughly for duration and difficulty. Systems must be easily adaptable to future task changes. The engineer and architect will need to refer to the *Design Manual* and to *California School Lighting Design and Evaluation* (Sacramento: California State Department of Education, 1978) for specifics regarding acceptable quantity and quality of light in classrooms.

### Natural vs. Artificial Light and Ventilation

Two major design decisions that are influenced by and that influence virtually all the foregoing topics in this section are (1) whether natural rather than artificial light will be the primary source of illumination; and (2) whether natural ventilation rather than air conditioning will be used in the building.

Natural light saves electrical power needed for artificial illumination and reduces cooling loads by eliminating heat buildup from lights. However, the use of natural light does not reduce the amount of artificial light that must be provided for in a building. It can only reduce the consumption of electricity or replace the use of artificial light at certain times and places in a building. The use of natural light requires proportionately more glazing (windows, skylights, light wells) in the building envelope, which increases heat transmission and infiltration. In winter this may increase heating loads; in summer solar heat gains may put increased demands on the air conditioning system.

Natural ventilation is acceptable when the quality of outdoor air is satisfactory and when noise problems do not exist. However, natural ventilation cannot penetrate deeply into a building; thus, it would not be appropriate for all building types. For example, natural ventilation would be suitable for a finger plan school but not necessarily a cluster plan school. Natural ventilation also involves increased infiltration and increased heating and cooling loads, which must be counteracted with additional use of energy.

School district personnel should discuss these design decisions and the energy trade-offs involved with their architect and engineer to arrive at the design that is most acceptable for their particular location and needs.

Most school architects and other professionals that Bureau of School Facilities Planning staff questioned, including representatives of the National Bureau of Standards, believe that at the present time artificial environments are more efficient overall than natural environments, primarily because they can be controlled more easily and because natural environments involve heating and cooling losses that may increase, rather than decrease, total energy consumption. This is not an endorsement of windowless schools, however. Windows of sufficient number and size should be provided to allow outside viewing and to serve as emergency exits.

**Natural light saves electrical power needed for artificial illumination and reduces cooling loads by eliminating heat buildup from lights.**

In the future techniques may be developed that will make the use of natural light and ventilation systems more desirable. The ideal school of the future will be lighted, heated, ventilated, and cooled as much as possible by natural means. The use of expensive and complicated mechanical equipment that requires ongoing maintenance and replacement of parts and that consumes depletable and costly energy resources will be reduced to a minimum.

### Load Management

Utility companies vary electricity rates for major users on the basis of both time of day and demand (rate of consumption). Rates are higher during peak load times (times of maximum demand by all customers of the utility company), such as the middle of the day, and lower when the load slacks off; that is, the middle of the night. The demand charge for an individual facility is determined by the highest electricity demand recorded during the month (computed in 15-, 30-, or 60-minute intervals), even if that level was reached only once. For example, if a school's demand reached 500 kilowatts only once during the month and was 450 kilowatts for the rest of the month, the school would be charged for 500 kilowatts of demand, in addition to so much per kilowatt-hour and peak kilowatt-hour.

Many techniques are being developed to "overcome" time-of-day pricing and demand charges. Refrigeration systems may be operated during the cool nighttime hours, when electricity rates are low; and the chilled water can be stored in a large storage tank until needed to cool the building the next day. Computers, programmed for load management, can turn off equipment on a priority basis to keep maximum demand below a certain desired level.

School districts should contact utility company customer service representatives, who can explain utility operations, rates, services, and schedules and suggest ways of economizing.

# Suggestions for Existing Schools

Obviously, if a school was built in 1960, little can be done today about its location and shape and the direction that it faces. Measures can be taken, however, to conserve energy. Many of the suggestions given in this section were provided by school districts and architects; others were discovered during research by Bureau of School Facilities Planning personnel. Some of the suggestions should be helpful to every school district in the state. Others may not be applicable to particular schools or may require modification to meet an individual school's needs. A few might be expensive, but a district that can afford to pay fuel bills for wasteful energy practices can afford to make repairs that will, in time, more than pay for themselves in energy savings. However, before authorizing any remodeling, purchases, or maintenance contracts, districts should get expert advice.

### Suggestions for District Administrations

The following are some suggestions for school district administrators to consider in planning and implementing an energy conservation program.

#### Suggestions That May Require Minor Expenditures

Suggestions that would require school districts to make only minor expenditures are the following:

1. Form a district-level energy conservation team or committee that involves as many segments of the educational community as is practical. Name an energy manager to head the team and to coordinate its activities. Team members could include the following:
   - Building principals
   - Business manager
   - Energy manager
   - Maintenance and custodial staff supervisor
   - Representatives of teachers, the board of education, food service personnel, parent-teacher-student associations, and utility companies
   - Student representatives
   - Superintendent
   - Transportation staff supervisor

   The team should be charged with developing an energy conservation program to be followed by each school in the district. Ideas in this publication should aid in the development of the program, and the team may wish to add more of its own. It is suggested that a task force made up of administrators, custodians, parents, secretaries, students, and teachers be formed at each school to implement the district-level energy conservation program under the direction of the principal. A follow-up system may be needed to ensure timely implementation.
2. Develop a public information program to inform administrators, the community, maintenance staff, parents, students, and teachers about what is being done and why and to ask for their suggestions, comments, and cooperation. Keep records on energy savings, and display them. If school occupants can see evidence of energy savings, they may be inspired to continue conservation techniques and even to exceed goals. (The San Juan Unified School District in Carmichael and the Santa Clara Unified School District offer rebates on energy savings to individual schools to encourage conservation. Rebates at Santa Clara may be used for any facet of the school's educational programs. At San Juan they may be used only to purchase instructional supplies. San Juan also provides monthly consumption reports to each school to give constant "reinforcement to the schools that energy conservation is still a district-wide priority.")
3. Include the subject of energy conservation as part of the school curriculum. Utility companies have speakers, films, and printed materials available to assist teachers in presenting the energy conservation concept to their classes.
4. Use life-cycle costing for all major expenditures.
5. Provide inservice training for custodians and maintenance personnel. Do not expect untrained, unskilled personnel to be able to

repair and maintain sophisticated equipment properly. Even the most energy-conserving equipment will not conserve if it is operated inefficiently. Develop operations and maintenance procedures manuals, or obtain them from architectural or engineering firms; and keep them near equipment. Consider sending operations and maintenance staff to summer and evening classes in building maintenance and operations and to seminars offered by manufacturers.

6. Control the occupancy of school buildings. Adjust schedules if necessary for conservation. (Sacramento City Unified School District authorized staff schedule changes during summer, 1977, to reduce air conditioning loads. Certain employees were permitted to shift their work hours forward 1½ hours to reduce the number of persons on duty during the hottest part of the day and to allow a number of air conditioners to be shut down.) Consolidate summer and adult classes and community use to a few schools to reduce air conditioning, electricity, and heating use.
7. Set standards for lighting; heating, ventilating, and air conditioning; and water.
8. Establish a regular preventative maintenance program with periodic inspection and scheduled parts replacement and repair. Dirty or corroded equipment must work harder and uses more energy than equipment that is clean and properly cared for.

#### Suggestions That May Require Major Expenditures

Suggestions that may require districts to make major expenditures are the following:

1. Hire private or staff energy consultants to assist in developing energy management programs. Work with representatives of local utility companies. (The San Juan Unified School District and San Leandro Unified School District have employed full-time energy experts. Other schools have contracted with energy conservation consulting firms.)
2. Have an energy audit performed at each school. Audits will reveal how much energy is being used and how efficiently, and audit teams can suggest ways to reduce energy use and increase efficiency.

   Districts are encouraged to conduct their own preliminary audits; some, however, may be interested in one of the audit options discussed below. The *Energy Sourcebook for Educational Facilities* (Columbus, Ohio: Council of Educational Facility Planners, 1977) contains a nine-page systematic facility survey (audit) checklist that may be used as a model for an energy self-audit. Before any structural changes or changes in the heating, ventilating, or air conditioning system or lighting system are made, the proposed changes should be checked for compliance with Education Code sections 39101 and 39140. In addition, for uniformity the Bureau of School Facilities Planning suggests that all audits and recommendations be submitted to the bureau for review before recommended changes are made.

   The Public Schools Energy Conservation Service (PSECS), developed by Educational Facilities Laboratories, performs a low-cost, long-distance form of audit. Upon request the service sends data forms to be completed by the district for each school. The information, plus local weather data, is fed into a computer. The printouts provide a comparison of actual school energy use with what the use should be, based on guidelines established by the service, for schools of the same generic type. An on-site audit by an architectural or engineering firm will still be necessary for specific recommendations on building or equipment modifications. As of November 1, 1977, the costs for a Public Schools Energy Conservation Service audit were $30 for each elementary school and $50 for each secondary school. For more information write Educational Facilities Laboratories, 3000 Sand Hill Road, Building 1, Suite 120, Menlo Park, CA 94025.

   Local utility companies may send representatives to audit school energy use. Pacific Gas and Electric Company (PG and E), for example, plans to begin a school auditing program in September, 1978, using the Public Schools Energy Conservation Service computer system. By June, 1979, over 1,500 schools in the PG and E service area, which covers much of northern California, will have been inspected at no direct charge to their districts. The company plans to perform 1,500 school audits each year for the next two to three years. Its technicians will pinpoint energy problems at each school, recommend conservation solutions, and attempt to "raise the awareness levels" of persons in the schools regarding their use of energy. Most other utility companies in the state, like PG and E, have initiated some form of auditing program. In addition, the California Energy Commission was to adopt by July 1, 1978, standards that will *require* major utility companies to audit all commercial customers. The major utility companies involved are Los Angeles Department of Water and Power, Pacific Gas and Electric Company, Sacramento Municipal Utility District, San Diego Gas and Electric Company, and Southern California Edison Company.

3. Hire energy consultants to make a thorough on-site inspection of each building and a computer analysis of energy use. This can cost from $3,000 to $10,000 per building. Several districts, however, have contracted with energy conservation consulting companies that perform analyses of heating and cooling systems and make system modifications at no direct cost to the district. Payment is a substantial percentage of the dollar savings effected. If no energy is saved, no charge is made. (Audits of the building envelope, the lighting system, and other systems must still be done by other teams to achieve energy efficiency in these areas.) All district personnel who have been polled about such analyses in their districts have been enthusiastic about energy and cost reductions achieved. However, in some cases utility bills remained the same despite consumption reduction because of fuel price increases. Schools should reduce their energy consumption as much as possible by ordinary common sense conservation measures—lowered thermostats, added insulation, weatherstripping, and so forth—before bringing in an energy conservation firm to study and modify heating, ventilating, and air conditioning systems. Districts should also ensure that such firms do not profit from systems that they did not install. For example, a district that modifies the lighting system in a school at its own expense while a contract is in effect should retain the resulting savings in electricity costs.
4. Call upon the Bureau of School Facilities Planning for assistance. The bureau has also begun an audit assistance program for California schools. Districts desiring audits may request assistance from their field representative. When an audit is requested, a team will be formed by the bureau in cooperation with the district. A well-balanced audit team might include four or five of the following: (1) school district personnel—the director of operations and maintenance, district architect or engineer, and energy coordinator (if any); (2) state personnel—a Bureau of School Facilities Planning field representative and a California Energy Commission representative; and (3) community persons—representatives of the local utility companies and representatives of an energy consulting firm (involving cost to the district).

The Department of Energy has proposed establishing matching grants to assist states in conducting preliminary energy audits of schools, hospital buildings, and buildings owned by local governments and public care institutions. More information will be made available by the California Energy Commission when this proposed program is finalized.

### Suggestions with Regard to Equipment

Some suggestions for utilizing equipment in a more energy-efficient manner are provided below.

#### Suggestions That May Require Minor Expenditures

The following suggestions should require districts to make minor expenditures or no expenditures:

1. Turn off all equipment when it is not being used.
2. Minimize equipment use when possible. For example, keep photocopy machines on only part of the day, do not preheat ovens except when necessary, use ventilation fans sparingly, and operate dishwashers only when they are fully loaded. (Fullerton Elementary School District marks the doors of ovens that are in use so they will not be opened before baking time is up. Magnolia Elementary School District in Anaheim has reduced incinerator use from 10 hours a day to 4 to conserve natural gas.)

#### Suggestions That May Require Major Expenditures

The following suggestions may cause districts to make major expenditures:

1. Replace worn out, inefficient, or obsolete equipment and systems with energy-efficient ones.
2. Size equipment properly; equipment that is too large for the job wastes energy.

## Suggestions for Heating, Ventilating, and Air Conditioning

The suggestions below pertain to the heating, ventilating, and air conditioning systems.

### Suggestions That May Require Minor Expenditures

The following suggestions should require districts to make minor or no expenditures:

1. Set thermostats no higher than 68° F. (20° C.) in winter and no lower than 78° F. (26° C.) in summer. Advise students and staff to adjust their clothing to the seasons. In most areas of California, outside air may be used to cool classrooms if the outside temperature is 55° F. (13° C.) or less and the air conditioning system has an "economizer cycle" to allow this. Turn off systems or lower thermostats 5° to 10° F. (3° to 6° C.) overnight, on weekends, or in summer. Each district should determine on a school-by-school basis whether systems should be turned off or thermostats lowered depending on the climate of the area and the type of heating, ventilating, and air conditioning systems involved. (San Diego City Unified School District utilizes intrusion alarm systems that "hear" heaters switching on and off at night in classrooms where someone has forgotten to turn down the thermostat before leaving. Security records are routinely reviewed to help minimize the number of such occurrences.)
2. Adjust building warm-up time to the outside temperature; on mild days only 30 minutes may be required to warm up the building.
3. Disconnect or lock classroom controls on the thermostats to prevent "temperature tampering."
4. Let sunshine in on cold days, and use drapes or blinds to keep it out on warm, humid days. Closing drapes and blinds helps reduce the amount of glare and heat entering at the windows.
5. Reduce ventilation to the code minimum allowed. If possible, allow no outside ventilation during nonoccupancy hours when the weather is cold. Enough air will seep through the shell to ventilate the building adequately. Use this air instead of outside air for morning heating start-up.
6. Educate students and staff about not opening doors and windows unnecessarily when the school is being heated or cooled mechanically. Hold-open devices should be used only when necessary and should not be used to keep doors open for long periods. One school found that nearly two-thirds of the energy used in the building was directly lost through open doors, windows, cracks, and other outside openings. If the school is cooled with natural ventilation, the staff should be taught how to operate windows, and windows should be screened. In open plan schools where either natural or mechanical ventilation can be used, agreement should be reached so that one section does not have windows open while another has the heating, ventilating, and air conditioning system turned on.

### Suggestions That May Require Major Expenditures

The suggestions set forth below could require school districts to make major expenditures:

1. Install locking thermostats for heating, ventilating, and air conditioning equipment. Much energy is wasted by changing thermostat settings arbitrarily. Thermostats should also be on locked seven-day clock timers that automatically drop night and weekend temperatures 5° to 10° F. (3° to 6° C.); fuel consumption can be reduced 10 to 15 percent.[1] Appropriate school personnel should be taught how to use timers so that they do not inadvertently "sabotage" the system by such acts as removing the pins that trigger the automatic temperature setback controls.
2. Install heat recovery systems to "co-generate," or reuse, waste heat instead of exhausting it.
3. Caulk and weatherstrip doors and windows to prevent air leakage. Consider replacing windows and frames if they cannot be upgraded by caulking and weatherstripping.
4. Add reflective film to windows, or double glaze them. Metallic film coatings reflect solar rays, reducing air conditioning costs. Double-glazed windows have roughly double the thermal resistance of single-glazed windows.
5. Reduce glass area if justified. The loss of natural light and the necessary increase in artificial illumination may be more than offset by the gain in energy conservation through reduced heating and cooling loads.

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[1] *Schoolhouse,* No. 13 (November, 1973), 3.

6. Zone the heating, ventilating, and air conditioning systems so that the use of one room will not require heating or cooling the entire school.
7. Add economizer cycles to all units as needed. Economizer cycles use "free cooling" by taking in outside air when the outdoor temperature is less than that indoors.
8. Add insulation. Adding insulation to walls is not often possible, but insulation can be added to roofs when they are replaced. Insulate also heating, ventilating, and cooling ducts and all hot and chilled water pipes.
9. Put spark pilot lights on all gas-fired heaters and water heaters.
10. Shade windows and walls with louvers, overhangs, trellises, and trees to reduce solar heat gain. Inside use shades, drapes, and venetian blinds.
11. Consider adding a solar system for space heating or cooling if economically justified by life-cycle costing.
12. Maximize landscaping, and minimize paving around buildings.

## Suggestions for Lighting

Suggestions pertaining to lighting are provided below.

### Suggestions That May Require Minor Expenditures

The following suggestions should require school districts to make only minor expenditures:

1. Turn off lights when not in use or when natural light is sufficient. (San Diego City Unified School District has placed reminder decals on switch plates.) Natural light can be used in many areas, including corridors, washrooms, shower and locker rooms, and storage and service areas. Fluorescent lights should not be switched off unless they will be idle for ten minutes or more. (This time limit is an estimate; follow the manufacturer's recommendations for the particular lamps used.) Even with modern fluorescent lamps, nearly 80 percent of consumed energy ends up as waste heat. Turning off unneeded lights will help reduce the amount of waste heat and ease the load on the air conditioning system.
2. Reduce lighting levels to minimum requirements. (See *California School Lighting Design and Evaluation,* and consult a Bureau of School Facilities Planning representative before making substantial changes in lighting.)
3. Eliminate display and decorative lighting.
4. Have custodians turn off lights room by room as they finish cleaning, or schedule daytime cleaning if possible.
5. Reduce "on" time for outside lighting or the amount of outside lighting if building security will not be affected.

### Suggestions That May Require Major Expenditures

The suggestions offered below may require districts to make major expenditures:

1. Replace incandescent lamps with fluorescents, or use incandescents of lower wattage. Consider the new "energy saving" fluorescent tubes on the market. Fluorescent lamps are three times as efficient as incandescent lamps. Consider the more efficient high intensity discharge (HID) lamps—metal halide or high pressure sodium—for gymnasiums and multiuse or exterior areas. (Yosemite Union High School, Yosemite Union High School District, Oakhurst, uses indirect high pressure sodium lighting in classroom areas.)
2. Install localized switching. Whenever natural light is sufficient to perform necessary visual tasks, the bank of lights next to the windows may be switched off. Photosensitive controls will do this automatically. If controls are not photosensitive, however, explain the proper use of switches and the importance of such use to teachers.

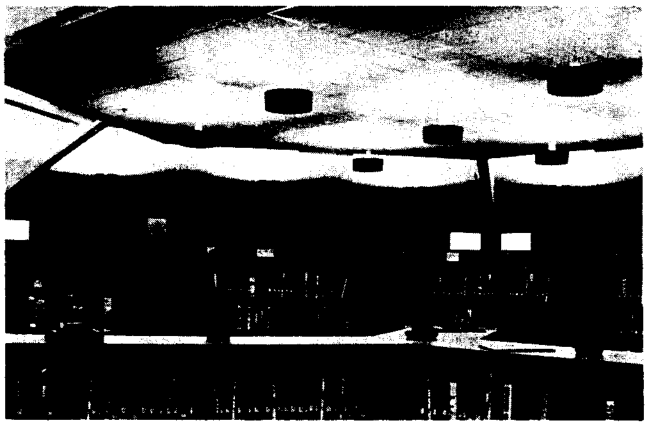


Photo courtesy of Schoenwald, Thomas, Harris, Norwood, House, Oba, Architects, Fresno

**The lighting system at Yosemite Union High School, Yosemite Union High School District, Oakhurst, is an excellent example of indirect high pressure sodium lighting. The 16- to 25-foot-high (4.9 to 7.6 metres) wood plank ceiling is stained white to alter the orange colored light that is typical of such lighting systems. Ballasts are mounted in the attic to prevent noise problems.**

3. Paint walls and ceilings light colors, and keep them clean. Dark colors and dirt can reduce illumination by up to 40 percent.
4. Investigate the use of seven-day clock timers for interior lighting. Photoelectric cells that turn outdoor lights on and off automatically may be a good investment. Ensure that cells are not oversensitive and trigger in fog or on cloudy days.

## Suggestions for Maintenance

The following are suggestions for saving energy in the area of maintenance.

### Suggestions That May Require Minor Expenditures

Districts undertaking the following may have to make only minor expenditures:

1. Keep all mechanical equipment in top operating condition.
2. Clean light fixtures and bulbs frequently, and replace bulbs when necessary. Unremoved dirt and dust can reduce efficiency by 10 to 12 percent in six months and 40 percent in two years. Fluorescents should be changed after 80 percent of lamp-life is used. After that time they use the same amount of energy but produce less light.
3. Service air conditioners on a regular basis. Check and repair cooling towers; replenish refrigerant; and examine fans, pumps, compressors, and other rotating equipment for poor seals, belt slippage, and other defects. Calibrate controls, and change filters.
4. Service furnaces regularly. Adjust fuel/air ratios, check thermostats, and calibrate other controls.
5. Ensure that doors and windows operate properly.

### Suggestions That May Require Major Expenditures

Major expenditures may be required to implement the following:

1. Employ full-time maintenance specialists.
2. If hiring full-time maintenance personnel is not feasible or desirable, hire outside specialists to service furnaces and the air conditioning system and to calibrate controls on a regular basis.

## Suggestions for Transportation

Ways to save energy in the area of transportation are suggested below.

### Suggestions That May Require Minor Expenditures

The following may require only minor expenditures:

1. Encourage walking, bicycling, and car pooling for both staff and students. Request staff to form car pools when traveling on official business in district vehicles. Increase the requirements for distances that children must walk to school and to bus stops. Furnish bike racks, and provide adequate security for bicycles from theft and vandalism.
2. Develop contingency plans for gas rationing. Such plans may involve routing buses on main roads only.
3. Eliminate the operation of buses that are not truly needed. Use the smallest vehicle practical for the job.
4. Install trip recorders to record data on vehicle operation. Use this information to reduce the consumption of gas and oil.
5. Audit fuel use on a month-by-month basis. Include prices, suppliers, bulk storage data, delivery dates, and practices. Analyze fuel availability and current needs.
6. Schedule regular maintenance and tune-ups. Correct faulty spark plugs, points, and carburetion. Maintain and clean pollution controls. Keep accurate records for maintenance and fuel consumption, oil changes, lubrication, and the like.
7. Keep gas tanks full to avoid excessive evaporation. Keep tanks locked.
8. Make sure that bus tires are properly inflated; soft tires increase gas consumption.
9. Use computer scheduling for bus routing if feasible.
10. Eliminate overlapping of routes. Combine elementary and secondary school bus routes.
11. Centralize pickup and return points. Space stops as far apart as is feasible.
12. Minimize or eliminate staggered school schedules.

13. Fill buses to capacity by sharing bus runs with other districts or nonpublic schools where possible.
14. Avoid "deadheading" (returning from a trip with no load) as much as possible.
15. Contract with parents to provide transportation in remote areas.
16. Train bus drivers for better fuel economy. Reduce speed.
17. Train new drivers on existing runs while deadheading.
18. Avoid courtesy stops.
19. Avoid full-throttle operation.
20. Turn off the engine when loading and unloading children or when the bus will be idling for more than 2 minutes.
21. Reduce bus warm-up time to 3 minutes, and drive slowly for the first few miles until the vehicle warms up.
22. In driver education classes teach fuel-conserving driving habits.
23. Fill driver-training cars to capacity.
24. Reduce the number of miles driven for each driver-training lesson. Reduce speed.
25. Limit freeway and highway driving in driver-training classes.
26. Use simulators and driving ranges whenever possible for driver education classes.
27. Reduce field trips and activity trips to those most necessary.
28. Establish minimum and maximum distances for field and activity trips.
29. Combine trip requests for more than one school to ensure full loads. Whenever possible, share buses with other districts to athletic events.

#### Suggestions That May Require Major Expenditures

Major expenditures may be required to implement the following suggestions:

1. Eliminate buses and cars that use excessive amounts of gas, and replace them with the smallest, most economical vehicles possible. Consider purchasing battery-operated vehicles and economy or compact cars for use in a motor pool.
2. Install two-way radios to direct operations and to redirect buses when necessary.

### Suggestions Pertaining to Water

Water conservation per se is not within the scope of this publication; however, the conservation of water may have the end result of reducing the consumption of gas and electricity and vice versa.

#### Suggestions Requiring Minor Expenditures

The following suggestions should require only minor expenditures:

1. Reduce water temperature to 90°–120° F. (32°–49° C.) or less except for dishwashing. (The Office of the San Diego County Superintendent of Schools has reduced hot water heater temperatures to 80° F. [27° C.] except for the water heater supplying the lunchroom dishwasher.)
2. Turn off showers when they are not being used.
3. Repair leaking fixtures immediately.
4. Turn off gas-fired swimming pool heaters, or reduce pool temperatures.

#### Suggestions That May Require Major Expenditures

Major expenditures may be required to implement the following suggestions:

1. Install water restrictors on shower heads to reduce hot water use.
2. Install a master control or clock timers on showers.
3. Install solar collectors to heat hot water or swimming pools.

# Appendix A
# Solar Projects, 1978

| Function | Number of projects | Facility | School district | County | Status |
|---|---|---|---|---|---|
| Building cooling | 3 | El Camino Real Elementary School | Irvine Unified | Orange | Operational |
| | | San Anselmo Elementary School | Oak Grove Elementary | Santa Clara | Funded |
| | | University High School | San Diego City Unified | San Diego | Ready to bid |
| Building heat | 10 | Green Elementary School | San Diego City Unified | San Diego | Operational |
| | | Hancock Elementary School | San Diego City Unified | San Diego | Operational |
| | | Doyle Elementary School | San Diego City Unified | San Diego | Under construction |
| | | University High School | San Diego City Unified | San Diego | Ready to bid |
| | | Jean Farb Elementary School | San Diego City Unified | San Diego | Under construction |
| | | Vista Grande Elementary School | San Diego City Unified | San Diego | Under construction |
| | | North County Development Center | Alameda City Unified | Alameda | Under construction |
| | | El Camino Real Elementary School | Irvine Unified | Orange | Operational |
| | | South High School Gymnasium | Torrance Unified | Los Angeles | Operational |
| | | West High School Gymnasium | Torrance Unified | Los Angeles | Operational |
| Domestic hot water | 10 | Mountain Empire Junior High School–Mountain Empire Senior High School | Mountain Empire Unified | San Diego | Operational |
| | | Valley Center Middle School | Valley Center Union Elementary | San Diego | Operational |
| | | Chauncy L. Jerabek Elementary School | San Diego City Unified | San Diego | Under construction |
| | | University High School | San Diego City Unified | San Diego | Ready to bid |
| | | Jean Farb Elementary School | San Diego City Unified | San Diego | Under construction |
| | | Vista Grande Elementary School | San Diego City Unified | San Diego | Under construction |
| | | Doyle Elementary School | San Diego City Unified | San Diego | Under construction |
| | | Grossmont High School | Grossmont Union High | San Diego | Operational |
| | | South High School Gymnasium | Torrance Unified | Los Angeles | Operational |
| | | West High School Gymnasium | Torrance Unified | Los Angeles | Operational |
| Swimming pool heat | 10 | Encina High School | San Juan Unified | Sacramento | Operational |
| | | Lewis Junior High School | San Diego City Unified | San Diego | Under construction |
| | | Marston Junior High School | San Diego City Unified | San Diego | Under construction |
| | | El Cajon Valley High School | Grossmont Union High | San Diego | Operational |
| | | Monte Vista High School | Grossmont Union High | San Diego | Under construction |
| | | Granite Hills High School (Montgomery Pool) | Grossmont Union High | San Diego | Under construction |
| | | Timpany Center (handicapped) | Santa Clara City Unified | Santa Clara | Being designed |
| | | Special Education Facility, Hesperia | San Bernardino City Unified | San Bernardino | Operational |
| | | McClymonds Senior High School | Oakland Unified | Alameda | Under construction |
| | | Development Center for the Handicapped | Glendale Unified | Los Angeles | Operational |

## Appendix B

# Some Recent Energy Responsive Projects (Other Than Solar Projects)

| Function | Facility | School district | County | Status |
|---|---|---|---|---|
| Two diesel generators to power chiller and lighting on a standby basis<br>Heat recovery for building heat from diesel generators<br>Computerized controls<br>Heat recovery for building heat from light fixtures | Chauncey L. Jerabek Elementary School | San Diego City Unified | San Diego | Under construction |
| Heat recovery for building heat from light fixtures | Green Elementary School and nine others | San Diego City Unified | San Diego | Operational |
| Computerized controls<br>Heat recovery for building heat from light fixtures | Hancock Elementary School | San Diego City Unified | San Diego | Operational |
| Indirect high pressure sodium lighting | Yosemite Union High School | Yosemite Union High | Madera | Operational |

## Appendix C

# Components of a Good Energy Management Program

- The district appoints an energy manager.
- The program is based on detailed, accurate and on-going reporting of energy consumption. Audits provide the information needed to determine both immediate changes in operating and maintenance procedures, building use and scheduling and long-range capital investments in modifications to buildings and equipment.
- The program is developed and examined in terms of cost benefits.
- The program provides on-going and accurate information to all members of the school and community.
- Goals of the program are clearly stated and specific in terms of what is to be accomplished, how it is to be accomplished, by whom, at what cost, over what period of time, and with what anticipated result.
- Program activities are monitored and evaluated on a regular basis.
- Experts from local businesses, government and utility companies are recruited to help with specific defined aspects of the program. . . .
- Meaningful involvement of staff, students and community is maintained.

Source: *School Energy Crisis: Problems and Solutions.* Produced by Shirley Boes Neill. Arlington, Va.: American Association of School Administrators, 1977, p. 53.

# Appendix D
# Tips on Hiring Outside Consultants

*School districts should:*

- Know about possible energy savers in schools.
- Have their staffs tone up controls and handling equipment, if possible, before bringing in consultants.
- Check out the consultant. Ask, "What have you done? Where? For whom?" Look particularly at the consultant's background and record on energy conservation in schools or in buildings similar to schools; for example, hospitals and office buildings.
- Check with the consultant's peers as to capability, reputation, and performance. Check with persons in a related but not identical profession.
- Try using the same techniques used in hiring a teacher for specialized purposes. Go through the same kind of screening techniques.
- Involve the custodial staff and principals in data collection.
- Be ready to provide records of past utility costs; building plans and specifications; data on installed equipment (manufacturers' information, age and type of equipment, fuel used); information on operational procedures; and past maintenance records.
- Assign a specific person to work with the consultant.
- Require a written report of all systems surveyed and of suggested modifications, including costs, savings, and pay-back periods.
- Consider as a plus, but not an overriding factor, the consultant's certification. Also check the consultant out by calling the appropriate local office of the consultant's professional organization.

*School districts should not:*

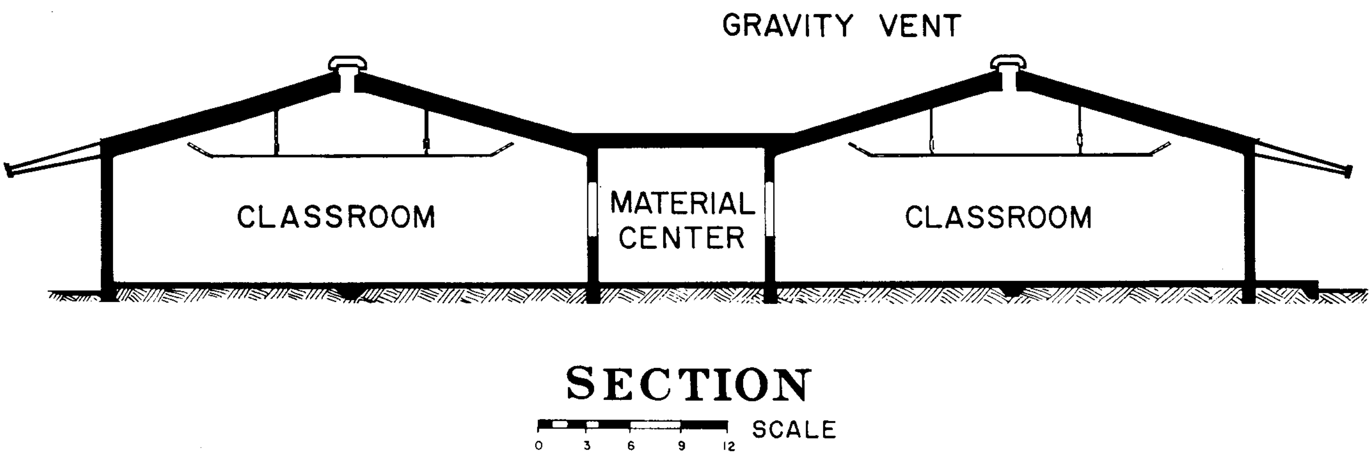
- Ask for an open-ended study. The study should be specific.
- Expect mechanical engineers or other consultants to have a panacea.
- Look only to the large contractors. Small firms may handle the job as well or better.
- Look only at the consultants who are advertising themselves as "energy specialists."
- Be misled by colorful brochures or a well-appointed office.
- Expect that each recommendation presented by the consultant will be acceptable or feasible.
- Keep quiet if they feel they've been "taken" by a consultant. They should inform the California Energy Commission, Department of Education, and the appropriate professional organization.
- Believe people who say energy problems can be solved by taking one simple step: buying their product. In most cases a variety of solutions will be needed.

Adapted from *School Energy Crisis: Problems and Solutions.* Produced by Shirley Boes Neill. Arlington, Va.: American Association of School Administrators, 1977, p. 49.

Appendix E
Section Drawing

# Canyon Elementary School

Canyon Union Elementary
School District




**SECTION**

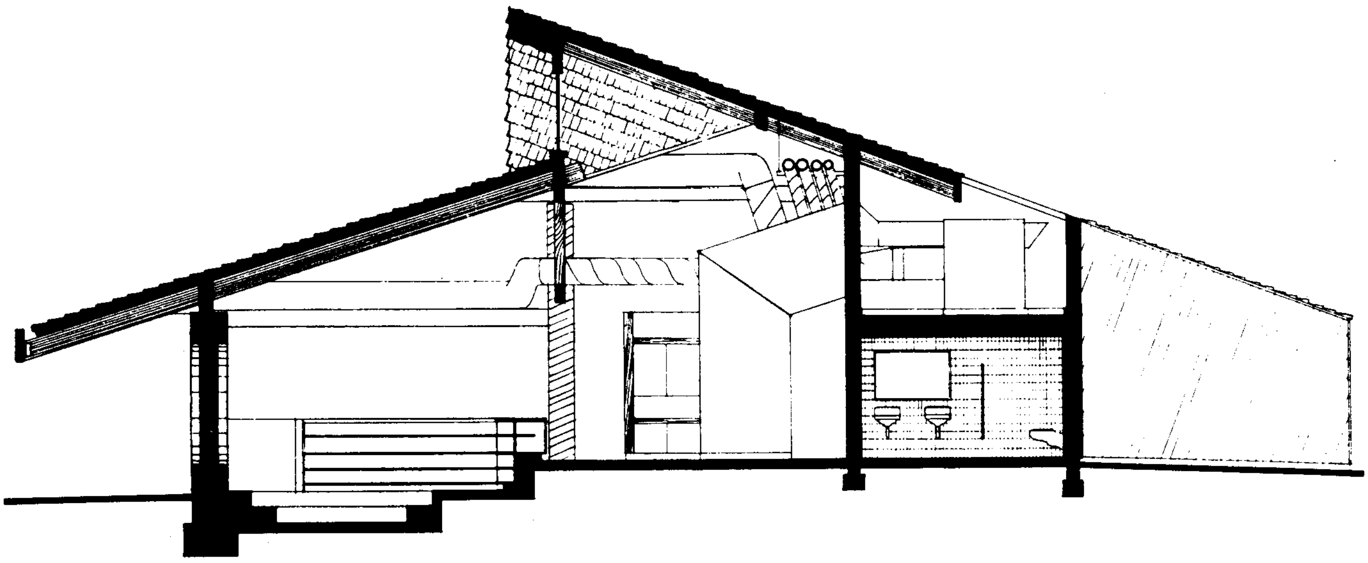
Smart and Clabaugh, Architects, Redding

This school offers an excellent example of the use of natural ventilation.

## Appendix F
## Section Drawing

# Culverdale Elementary School

Irvine Unified School District



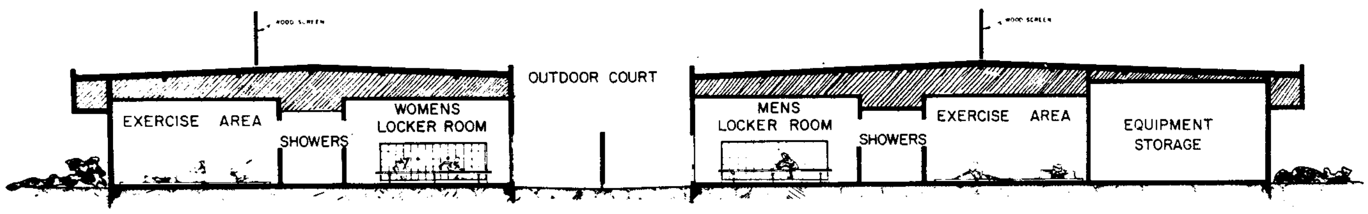
Knowles and La Bonte, Architects, Irvine

This school offers an excellent example of the use of natural light and ventilation.

Appendix G
Section Drawing

# Foothill High School

Amador Valley Joint Union
High School District




SECTION

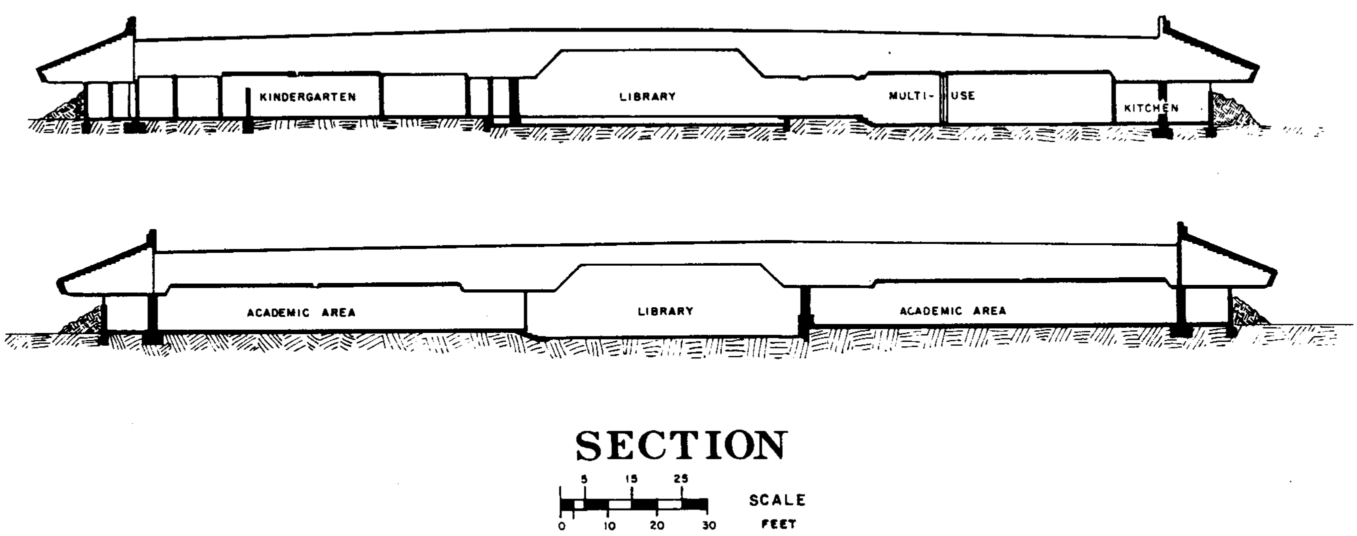
Ron Martyn, Associated Architects, Oakland

This school offers an excellent example of the use of natural light in shower rooms and locker rooms.

Appendix H
Section Drawing

# Oak Ridge Elementary School

Oak Grove Elementary
School District



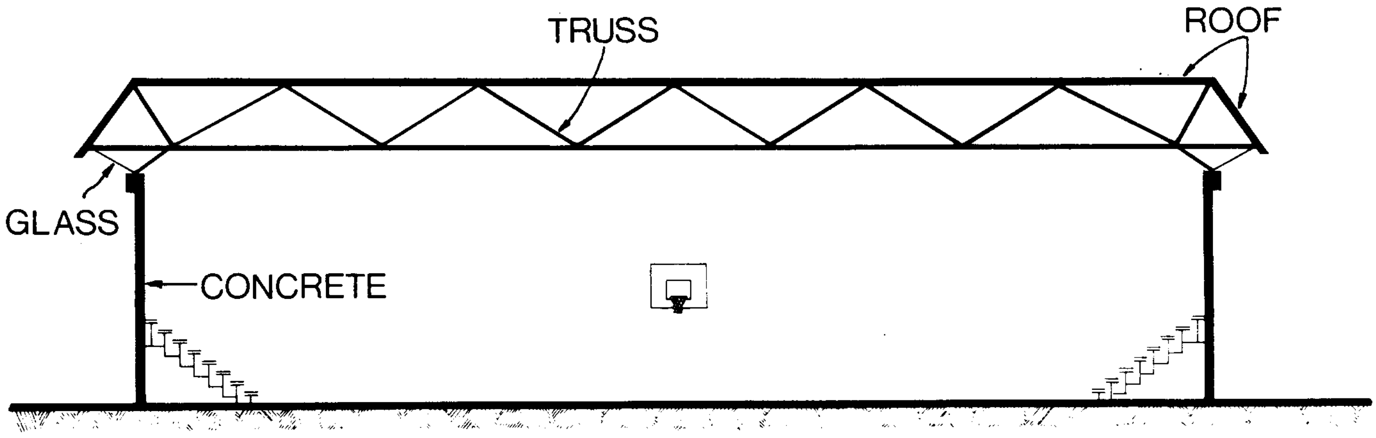

Porter, Jensen, Hansen, Manzagol, Architects, Santa Clara

This school is an excellent example of a compact (round) structure with earth berms.

Appendix I
Section Drawing

# Seaside High School Gym

Monterey Peninsula Unified
School District




Fred Keeble and George Rhoda, Architects, Monterey

This gym offers an excellent example of the use of natural light.

# Glossary

*Absorption refrigeration.* A type of air conditioning system that uses equipment much like that used in gas-burning refrigerators and air conditioners.

*Active solar system.* A system that uses mechanical devices such as pumps, fans, and motors to carry heat from solar collectors to storage and from storage to the interior space of the building.

*Artificial.* Produced or effected by people to imitate nature.

*Atrium.* A garden court within a building.

*Ballast.* A device used with an electric discharge lamp to provide the necessary circuit conditions for starting and to limit the operating current.

*Berm.* Earth banked against the concrete outside wall of a building to provide thermal insulation and landscaped to create an architectural facade. See also "Heat sink" and "Building mass."

*Breeder reactor.* A nuclear reactor that produces fissionable fuel and that consumes it. The new fissionable material is created by capture in fertile materials of neutrons from fission.

*Btu.* British thermal unit, a unit of heat energy. The heat required to raise the temperature of 1 pound of water 1° F. (0.6° C.) at sea level. About equal to the heat from a wooden match burned completely to ashes. A human body emits about 400 to 500 Btu per hour.

*Building mass.* The weight of a building and the ability of that weight to stabilize inside temperatures and thus reduce the need for mechanical heating and cooling. Building mass can be used to store heat or cold until needed. See "Heat sink."

*Celsius.* Replacement of the name centigrade. A temperature scale based on the freezing (0° C.) and boiling (100° C.) points of water.

*Chimney effect.* The tendency of air or gas to rise when heated due to its lower density compared with that of surrounding air or gas. The chimney effect can be used in a building with a passive solar energy system to channel hot air out of the building. See also "Thermosyphon system."

*Clearstory (also clerestory) window.* A high window.

*Cogeneration.* A heat transfer process for using heat recovered from or absorbed in one part of a cycle to perform a useful function in another part of the cycle. See also "Heat recovery system."

*Collector panel.* A device for intercepting the sun's rays and converting them to heat, which is carried by water or air to storage.

*Colonnade.* An outside covered passageway or porch.

*Condenser.* A vessel in which a vapor (gas) is liquified by removal of heat.

*Conditioned space.* Interior building space that is heated or cooled by mechanical means.

*Conduction.* A process by which heat flows from a region of higher temperature to a region of lower temperature within a solid medium or between different mediums in direct physical contact. For example: One end of a rod is placed in a fire, heat is conducted through the rod, and soon the other end of the rod heats up.

*Convection.* The circulatory motion that occurs in a fluid (liquid or gas) at a nonuniform temperature owing to the variation of its density and the action of gravity; the transfer of heat by this circulation. For example: Air comes in contact with the heating fins of a baseboard heater, is heated, rises, and starts all air in the room circulating.

*Cost avoidance.* Keeping fuel bills relatively stable despite rate increases by reducing fuel consumption as much as possible. This does not result in actual dollar savings, because fuel bills may be the same as or even higher than before rates were increased. However, without conservation, bills would have increased to a much greater extent.

*Double-glazed windows.* Windows that have two sheets of glass or plastic in the frame, with an insulating air space between them.

*Economizer cycle.* A cycle of a heating, ventilating, and air conditioning system that allows cooling with outside air instead of refrigeration equipment when outside temperatures are suitable.

*Electric discharge lamp.* A lamp in which light (or radiant energy near the visible spectrum) is produced by the passage of an electric current through a metallic vapor or a gas.

*Energy audit.* A review of the design and operation of a facility with respect to potential reductions in energy consumption.

*Energy budget.* Maximum allowable energy consumption by a building.

*Envelope.* The shell or skin of a building.

*Fenestration.* The arrangement, proportioning, and design of windows and doors in a building.

*First-cost.* The initial cost to construct and equip a facility.

*Fluorescent lamp.* An electric discharge lamp in which a fluorescent coating (phosphor) transforms some of the ultraviolet energy generated by the discharge into light.

*Footcandle.* A measure of the amount of illumination on a surface.

*Fossil fuel.* Fuels derived from the remains of carbonaceous fossils, including petroleum, natural gas, coal, oil shale, and tar sands.

*Geothermal energy.* Energy extracted from the natural heat of the earth's interior.

*Glazing.* Glass, plastic, or other transparent material set into a window frame or used to cover solar collectors.

*Greenhouse.* A glass-enclosed room usually on the south side of a house or other building whose primary purpose is to collect heat for space heating. (Not to be confused with the traditional greenhouse, a separate structure in which plants are grown commercially or for private use.)

*Greenhouse effect.* The specific property of glass or plastic that allows it to transmit shortwave visible rays of sunlight but block longer wavelength invisible heat waves.

*Heat exchanger.* A device specifically designed to transfer heat between two physically separated fluids.

*Heat pump.* A refrigerating system, sometimes called a "forward-backward" air conditioner, that draws heat from inside a building and expels it outside to cool and that draws heat from outside air and pumps it inside to heat.

*Heat recovery system.* A heating, ventilating, and air conditioning system that recovers waste heat from lights, kitchens, and boilers, for example, and returns it to the building for space or water heating or storage. See also "Cogeneration."

*Heat sink.* Material such as masonry, adobe, concrete, stone, or water that stores heat until needed (when the surrounding temperature is lower than that of the sink). See also "Building mass."

*HID lamps.* High intensity discharge lamps, such as high pressure sodium, mercury vapor, and metal halide, that can deliver from two to five times the lumens per watt as the standard incandescent lamp.

*HVAC system.* Heating, ventilating, and air conditioning system.

*Hydroelectric energy.* Energy created by falling or moving water.

*Hydrogenation.* Heating solid wastes at high pressure to create fuel.

*Incandescent lamp.* An electric lamp in which a filament is heated in a vacuum by an electric current to produce light.

*Infiltration.* Air leakage into a building through open doors and windows, cracks around doors, windows and other openings, construction joints, and through building materials.

*Insolation.* The amount of solar radiation received by an object such as a solar panel, measured in Btu/hr./sq. ft.

*Insulation.* A material with a relatively high resistance to heat flow that is used principally to retard the flow of heat.

*Kilowatt-hour (kWh).* One thousand watts of electricity used for 1 hour.

*Lamp.* A source of light made by human beings; for example, an incandescent light bulb and fluorescent tube.

*Life-cycle costing.* Considering long-range operating and maintenance costs before awarding construction or equipment contracts or making any major purchase.

*Load management.* Adjusting a building's operation and equipment to cope with utility company artificial time-of-day pricing policies; that is, scheduling major usage at a time of day when rates are lowest or turning off equipment sequentially to keep consumption at a predetermined maximum at times of day when rates are highest.

*Lumen.* A unit of light.

*Luminaire.* A complete lighting unit consisting of a lamp or lamps together with parts designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

*Microclimate.* Weather conditions unique to a specific limited area, such as a school site.

*Mullion.* A vertical strip dividing the panes of a window, door, or screen.

*Natural light/heat.* Light/heat from the sun that can be used to illuminate or warm a building.

*Natural ventilation.* Outdoor air (breezes) that can be used to cool or freshen a building as it flows through open windows or vents.

*Nondepletable energy source.* An energy source, such as wind or solar energy, that is not depleted by use.

*Nuclear energy.* Energy, largely in the form of heat, produced during nuclear chain reactions. This thermal energy can be transformed into electrical energy.

*Nuclear fission.* The splitting of a heavy nucleus into two atoms of lower atomic weight, involving the release of energy.

*Nuclear fusion.* The formation of a heavier nucleus from two lighter ones (such as hydrogen isotopes) with the attendant release of energy.

*Ocean thermal gradients.* Areas at different depths in the ocean that have temperature differences of as much as 45° F. (25° C.). These gradients can be used to produce mechanical energy.

*Oil shale.* Sedimentary rock containing organic material from which liquid petroleum can be extracted.

*Passive solar system.* A system that uses the structure of the building (building mass, greenhouse) as both the collector and storage medium of solar heat. Passive systems may also include solar panels and move heat through nonmechanical means, such as conduction, convection, thermosyphon, and the chimney effect.

*Peak watt.* A watt used at the time of day when utility company rates are highest. See also "Load management."

*Photovoltaic conversion.* Conversion of sunlight directly into electricity through concentration of the sun's rays onto solar cells.

*Portico.* A porch or walkway with a roof supported by columns, often leading to the entrance of a building.

*Pyrolysis.* The conversion of organic materials into other compounds via the use of heat in an oxygen-deficient environment. Principal products are gases, oils, and char, a solid carbonaceous residue.

*Radiation.* Transmission of heat through space by wave motion; the passage of heat from one object to another without warming the space between. Sunshine, for example, heats up what it shines on but does not heat the intermediate air.

*Retrofit.* Addition or replacement of minor building components at small cost or of major systems at significant cost. Also called rehabilitation.

*Rotary heat wheel.* A type of heat recovery system in which a rotating metal cylinder absorbs waste heat from the exhaust air stream and transfers it to the other end of the cylinder. As incoming fresh air passes over the second end of the wheel, it is heated.

*Solar cell.* A device, often made of silicon, that converts sunlight directly into electrical energy.

*Solar thermal conversion.* Use of the sun's heat to make steam, which is used to generate electricity.

*Space heating.* Heating the interior area, or space, of a building, as opposed to hot-water heating.

*Task lighting.* Lighting provided for each of several individual work or study stations within an area as opposed to lighting provided uniformly for the entire area.

*Therm.* A unit of heat equal to 100,000 Btu.

*Thermosyphon system.* A solar heating system that uses natural convection to transport heat from the collector to an elevated storage tank. See also "Chimney effect."

*Trombe wall.* A passive solar system, invented by Felix Trombe, that uses a greenhouse to collect the sun's heat and a black concrete wall as a heat sink.

*Uranium.* A radioactive element that is the basic raw material of nuclear energy.

*Vestibule.* A small entrance hall or antechamber between two doors of a building; a lobby.

*Watt.* A unit of electric or heat power. One watt equals 3.4 Btu/hr.

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